Improved load frequency control of 2-area power system using nature inspired algorithm

Pasalapudi Sai Pavan Kumar[1], Idamakanti kasireddy[2], DSNM Rao[3], Ch. Phani Kumar[4]

[1,2,4] Department of EEE, Vishnu Institute of Technology, Bhimavaram.

[3]GokarajuRangaraju Institute of Engineering & Technology, Hyderabad,

Email: 20pa1d6002@vishnu.edu.in

Abstract

Automatic generation control is required in power systems to satisfy customer load requirements without disturbing the power quality with voltage and frequency swings. Any sudden load perturbations will cause a mismatch of power between generation and demand. Small disturbances can be self-managed by the synchronous generators. But the large disturbances may lead to an unstable system. In this case, speed governors come into action which is primary speed control. But the decline in frequency still exists from the nominal value. Therefore, to ensure the power quality, Automatic generation control is needed. The goal of Automatic generation control (AGC) is to hold system frequency at or very close to a specified nominal value with intelligent controllers (PID) which is a secondary speed control using frequency sensors.

Most of the methods used for automatic generation control are optimization control methods. The main goal is to improve the generation controller performance index by choosing a good optimal control algorithm so that we will get minimized change in frequency in a faster time. In this paper, we study & utilize some of the nature-inspired optimization algorithms to better regulate the automated production of linked power systems by using PID controllers. We compare these results of two area-connected thermal power systems with each algorithm and try to reduce the minimum frequency change mainly to get better settling time characteristics.

Keywords: Automatic Generation Control (AGC), Particle Swarm Optimization (PSO), Differential Evolution (DE), Artificial Neural Networks (ANN).

1. Introduction

One of the primary goals of the power system is to fulfil customer load requirements while satisfying important system constraints, such as voltage and frequency fluctuations that could create instability and, under more extreme circumstances, grid failures. Due to the rising need for electricity, power systems are now run as complex, interconnected systems. Three categories such as generation, transmission, and distribution are used to categorize the entire process.

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The role of the power system's components is to ensure steady operation, supply reliability, and quality. It is described as Automatic generation control (AGC). [1] In the interconnected power system, AGC's main objectives are to maintain each control area's frequency at a constant value and to set the tie-line power flows within a given tolerance range. We can adapt the real power outputs of the control area generators to the changing load requirements. It is also known as Load frequency control (LFC).

Tie-lines link each of the interconnected control areas. The overall generation capacity should be balanced with the total load requirement and losses for linked power networks to function reliably. The linearized model, which is the best scenario, is used by the majority of ideal techniques. [2, 3] The frequency of particular control regions and linked power exchange are the two relevant variables. A load frequency controller such as a proportional, integral, or PID is included in each control region to monitor the system frequency and linked power exchange. Area control error (ACE) is a combination of these two factors. Both the frequency of specific regions and the linked power exchange is maintained within the nominal values for the system to operate steadily. This issue is referred to as AGC or LFC. [4, 5]. A variety of control techniques have been created to enhance the functionality of interconnected power systems. Similar to this, a variety of creative techniques have been applied to enhance the system's dynamic performance.

In order to accomplish effective automatic generation control, controllers can be employed in conjunction with a variety of optimization techniques, including genetic algorithms, differential evolution algorithms, artificial neural networks, particle swarm optimization algorithms, etc. Thus, AGC is so needed in current power systems. The test systems used in this paper are explained in the next section.

2. TEST SYSTEM OF POWER SYSTEM MODEL

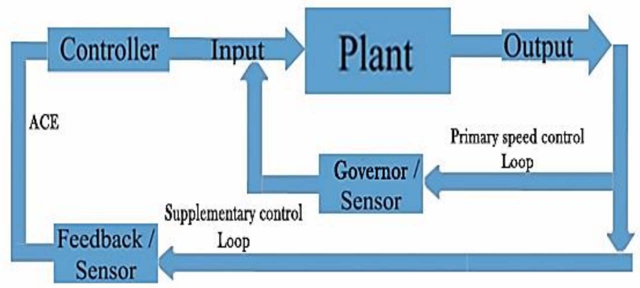

Figure 1. Test system

In Fig. 1, the feedback input to the load frequency controller is taken from area control error (ACE) for the improvisation of transient response characteristics of a supplementary control loop.

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3. Nature Inspired Algorithms

Nature Inspired algorithms fall under the category of meta-heuristics that incorporate randomness in the variables. [6] The development of these algorithms was inspired by natural phenomena, including Bacteria, [7] African bees, colony optimization, strawberry plants, [8, 9], etc.

As we are having so many nature-inspired algorithms we use Differential Evolution (DE), Artificial Neural Network (ANN), and Particle Swarm Optimisation (PSO) algorithms for the study purpose that are employed in this paper.

3.1. Differential Evolution (DE)

A population-based optimization approach is called the Differential Evolution algorithm (DE) [10, 11]. It functions with two populations that are represented by an older and a younger generation. A quick explanation of the optimization procedure is below:

a) Initialization: In this step initialize all the DE parameters required in the range interval [Lb, Ub] and create target vectors X was given as:

$$X = Lb + (Ub - Lb) * r \quad (1)$$

Where r= random matrix of order (1, d), d= no of input variables

b) Mutation: In this step, three parent vectors (X_1, X_2, X_3) are chosen for mutation from previously initialized target vectors and are used to create the child vector. The weighted difference between the two vectors is added to the other vector to produce a child vector which is also known as donor vector V. It is given as:

$$V = X1 + f * (X2 - X3) \quad (2)$$

Where f is a constant within the range (0, 2)

c) Crossover: In this step, the crossover of initially developed target vectors X and donor vector V are compared with probability range k for the creation of trial vector U. The trial vector U is later updated with the elements of the target vector or donor vector. It is given as:

$$U = X*(1-k) + V*k \quad (3)$$

Where, k is a constant of probability range {0,1}

d) Selection: In this step, the target vectors X are compared with trial vectors U and later updated with selected new best values of fitness function (ITAE). Now a new population is created due to the altering of target vectors X which are fed again for the mutation process. The cycle continues for the best tolerable optimized value and evolves for every generation.

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3.1.1. *Test system of two area power system model using DE algorithm*

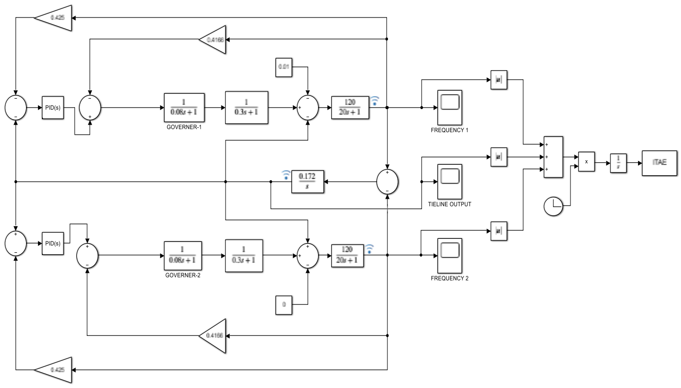
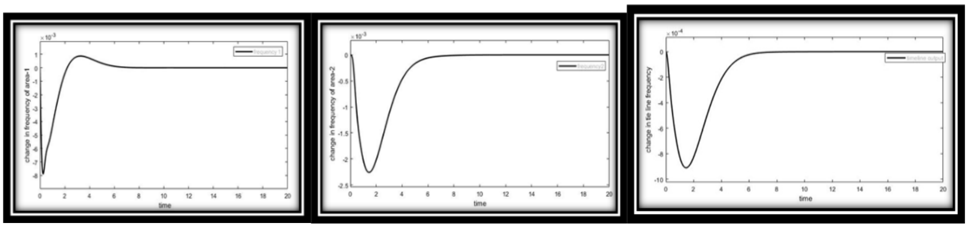


Figure 2. Modelling of test system simulation under one percent variation in area-1

Figure 2 shows the modelling of a load frequency control for test system. The specification values of every block in the system are taken from the base paper mentioned in [12].

3.1.2 Comparison of output results for change in frequency



(a). Area-1 frequency variation (b). Area-2 frequency variation (c). Tie-line frequency variation

Figure 3. (a), (b), (c) Characteristics of Test system

The sub-figures mentioned in Fig 3 give the characteristics of change in frequencies in both areas and tie lines of test system. The output frequency characteristics are obtained for the same values of DE optimized PID controllers in both the areas of power system for one percent variation in area-1 and output is given as: k_p=1.500, k_i=1.960, k_d=1.092, f_{min}=0.0281 for best settling time.

3.2. *Artificial Neural Networks (ANN)*

The best control commands are determined using an artificial neural network. [13] Even nonlinearities can be applied to it. While starting, the system settings are not necessary. Even if inputs to the system are momentarily lost or faults

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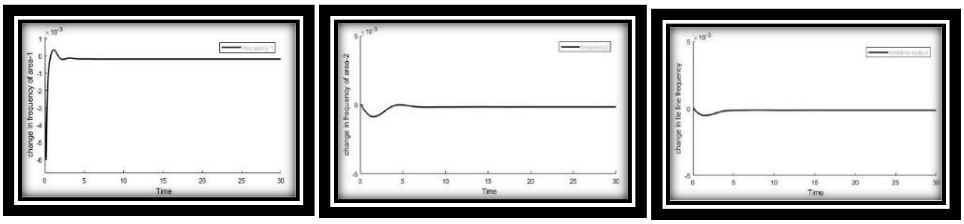
are introduced, it can still operate. The controller keeps working in the event of any breakdown, minimizing the requirement for decision-making support software. Initially make the outputs and inputs initialized. Initialize the weight values and the values of bases using functions like tansig, trainlm, logsig, etc. Following the initialization of the maximum number of training epochs, the results are displayed at every iteration with the error training. Once the system has successfully trained, you may begin the process of concluding it by generating a trained simulation system.

3.2.1 Test system of two area power system model using ANN algorithm

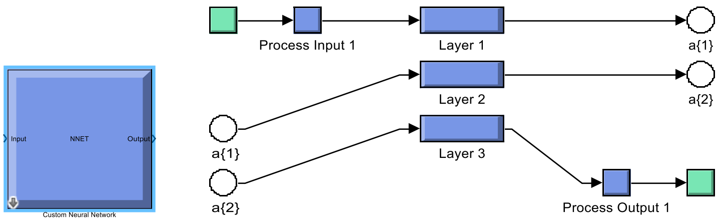
Figure 2 shows the modelling of a load frequency control for test system. The specification values of every block in the system are taken from the base paper mentioned in [12]. Only the controller in area-1 is trained by using ANN algorithm.

3.2.3 Comparison of output results in a change in frequency



(a). Area-1 frequency variation (b). Area-2 frequency variation (c). Tie-line frequency variation

Figure 4. (a), (b), (c) Characteristics of Test system



(a) (b)

Figure 5. (a) ANN trained controller and (b) ANN trained neural network structure

The sub-figures mentioned in Fig 4 gives the characteristics of change in frequencies in both areas and tie lines of test system. For training of ANN controller initially we had done extensive simulation and the values for gain are taken as k_p=1.400, k_i=1.600, k_d=1.400 for getting the input and output data. The output frequency characteristics are obtained for same values of ANN trained controller in area-1 and PID controller trained by extensive simulation in area-2 of power system for one percent variation in area-1. The drawback is that despite the load disruption,

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area-2 response still exhibits some inaccuracy with best settling time compared to DE algorithm.

The figure 5 (a) is the ANN trained controller obtained as output and figure 5 (b) gives the inside view of ANN controller which contains input layer, output layer and hidden layers. The output trained ANN controller is given below:

3.3. Particle Swarm Optimization (PSO)

For optimization issues, Kennedy and Eberhart developed the PSO algorithm [14]. It is one of the algorithms that draw inspiration from nature and is based on a simulation of the flock's behaviour of birds. It is mostly population-based and has gained popularity as a global optimizer, especially for issues where the decision variables are actual numbers. Since it simply requires the objective function for optimization, it differs from other optimization techniques. The main points of Particle swarm optimization are given as:

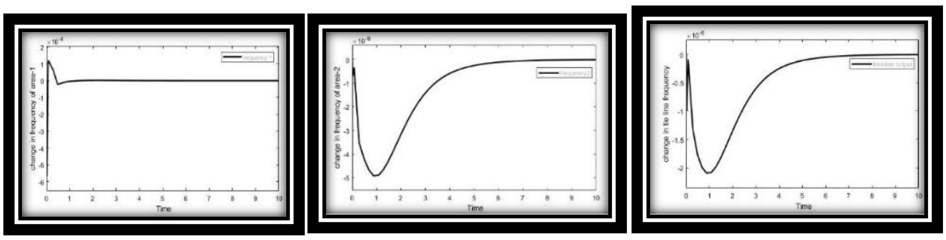
- Each particle in particle swarm optimization has an associated position, velocity, fitness value.
- Each particle keeps track of the particle best Fitness value and particle best Fitness position (Pbest).
- A record of global best Fitness position and global best Fitness value is maintained (Gbest)

3.3.1 Test system of two area power system model using PSO algorithm

Figure 2 shows the modelling of a load frequency control for test system. The specification values of every block in the system are taken from the base paper mentioned in [12].Only the controller is optimized by using the particle swarm optimization algorithm.

3.3.2 Comparison of output results in a change in frequency

The sub-figures mentioned in Fig 11 gives the characteristics of change in frequencies in both areas and tie lines of test system-1 and test system-2. The output frequency characteristics are improved for test system-2 as compared to the original test system-1 for same values of PSO optimized PID controllers in both areas of power system for one percent variation in area-1. Here we use Rosenbrock solver settings while simulation at a tolerance of 1e+6 and for optimisation. The values of k_p, k_i, k_d are 1.0e+03 * 0.8918, 1.0000, 0.2838 for best settling time.



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(a). Area-1 frequency variation(b). Area-2 frequency variation(c). Tie-line frequency variation

Figure 6. (a), (b), (c) Characteristics of Test system

4. CONCLUSION

In ANN optimized Algorithm, by comparative analysis, the output frequency characteristics are improved compared to DE for the same values of ANN trained controller in area-1 and PID controller trained by extensive simulation in area-2 of power system for 1% step change in area-1. But the disadvantage is that we can still see some error in the area-2 response which is not having the load disturbance. Even though it gives better settling time compared to DE-optimized results.

In PSO optimized Algorithm, by comparative analysis, the output frequency characteristics are improved compared to ANN for the same values of PSO optimized PID controllers in both the areas of the power system for 1% step change disturbance in area-1. Here we use Rosenbrock solver settings while simulation at a tolerance of 1e+6 for optimization.

Thus, by comparing all these algorithms, Particle swarm optimization (PSO) provides better optimization results when comparing all these techniques of two area-interconnected power systems, and the Test system-2 improves network performance when compared to the Test system-1 with the least settling time of change in frequency.

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