OPTIMIZATION EFFECTS ON THE LOAD FREQUENCY OF POWER SYSTEM: A REVIEW

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Abstract: This paper presents a small review of the optimization techniques which are used to regulate an objective function to get best outputs with a large stability limit. The base system of all the papers studied is the Power system model using a transfer function on which controller is the conventional type PID controller.in recent years authors have provided the understanding and Implementation of PSO algorithms and Artificial intelligence to tune any system parameters for the outputs. Hence this review paper covers the work of modelling a system in the first part and control techniques with the PSO implementation in the later stages.

Key words: Review paper, PSO, Power system Model, Frequency Control

1. INTRODUCTION

According to practical point of view, the load frequency control problem of interconnected power system is much more important than the isolated (single area) power systems. Whereas the theory and knowledge of a isolated power system is equally important for understanding the overall view of interconnected power system.

Generally, now days all power systems are tied with their neighboring areas and the Load Frequency Control Problem become a joint undertaking. Some basic operating principle of an interconnected power system is written below:

1. The loads should strive to be carried by their own control areas under normal operating conditions, except the scheduled portion of the loads of other members, as mutually agreed upon.
2. Each area must have to agree upon adopting, regulating, control strategies and equipment which are beneficial for both normal and abnormal conditions.

If there is interconnection exists between two control areas through tie line than that is called a two-area interconnected power system. Fig. 1.1 shows a two-area power system where each area supplies to its own area and the power flow between the areas are allowed by the tie line.

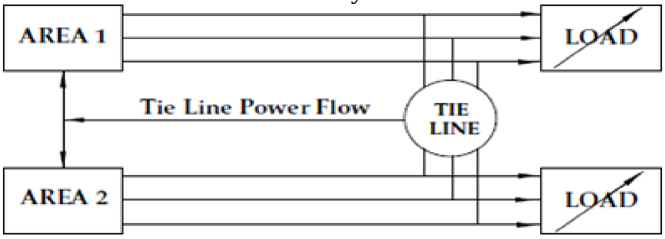


Figure 1: Two area interconnected power system

In this case of two area power system an assumption is taken that the individual areas are strong and the tie line which connects the two area is weak. Here a single frequency is characterized throughout a single area; means the network area is ‘strong’ or ‘rigid’. There may be any numbers of control areas in an interconnected power system.

2. LITERATURE STUDIED FOR THE RESEARCH

The first attempt in case of LFC has to control the power system frequency by the help of the governor. This technique of governor control was not sufficient for the stabilization of the system. so, a extra supplementary control technique was introduced to the governor By the help of a variable proportional directly to the deviation of frequency plus its integral. This scheme contains classical approach of Load Frequency Control (LFC) of power system. Cohn has done earlier works in the important area of LFC. Concordia et al [1] and Cohn [2] have described the basic importance of frequency and tie line power and tie line bias control in case of interconnected power system.

The revolutionary concept of optimal control (optimal regulator) for LFC of an interconnected power system was first started by Elgerd[3]. There was a recommendation from the North American Power Systems Interconnection Committee (NAPSIC) that, each and every control area should have to set its frequency bias coefficient is equal to the Area Frequency Response Characteristics (AFRC). But Elgerd and Fosha [3-4] argued seriously on the basis of frequency bias and by the help of optimal control methods thy presented that for lower bias settings, there is wider stability margin and better response. They have also proved that a state variable model on the basis of optimal control method can highly improvise the stability margins and dynamic response of the load frequency control problem.

The standard definitions of the different terms for LFC of power system are heaving the approval by the IEEE STANDARDS Committee in 1968 [5]. The dynamic model suggestions were described thoroughly by IEEE PES working groups [5-6]. Based on experiences with real implementation of LFC schemes, various modifications to the ACE definition were suggested time to time to cope with the changing environment of power system [7, 8, 9, and 10].

2.1 Literature Review on LFC Related to Control Techniques

The continuing work by numerous numbers of engineers of control engineering has generated links between the closed loop transient response (in time domain) and frequency response. The research is carried over using different classical control techniques. It is revealed that it will result comparatively large transient frequency deviation and overshoots [3, 15]. Moreover, generally the settling time of frequency deviation for the system is relatively long (10 to 20 seconds). The LFC optimal regulator design techniques using optimal control theory stimulates the engineers of control engineering to design a control system with optimal controller, in reference to given performance criterion. Fosha and Elgerd
[4] were the two persons who first presented their work on optimal LFC regulator using this process. A power system of two identical areas interconnected through tie line heaving non reheat turbine is considered for investigation.
R. K. Cavin et al [16] has considered the problem of LFC for an interconnected system from the theory of optimal stochastic system point of view. A algorithm based on control strategy was developed which gives improvised performance of power system for both small and large signal modes of operation. The special attractive feature of the control scheme proposed here was that it required the recently used variables. That are deviation in frequency and scheduled inter change deviations taken as input.

Zafer Bingul et al. conducted their research on 'Tuning of Fractional PID Controllers Using PSO Algorithm for Robot Trajectory Control'. In their research of robot trajectory control, Fractional order PID (FOPID) controller is tuned with PSO and the results are compared with Fuzzy logic controller & PID tuned by PSO. Proposed method of FOPID controller using PSO is better than other techniques [1].
V. K. Kadiyala et al. in their research paper titled 'Design and implementation of fractional order PID controller for Aero fin control system' proposed a Fractional order PID (FOPID) controller of electromagnetic actuator (EMA) system for Aero fin control (AFC) using PSO. The EMA is realized with permanent magnet brush DC motor which is driven by a constant current driver. Using the non-linear model of EMA-AFC system which includes the non-linearities of DC motor, an FOPID position controller is designed using different soft computing techniques like PSO in SIMULINK so that the system satisfies all the design requirements. The proposed method gives results better than conventional methods for Electromagnetic actuator (EMA) system for AFC [2].
C. H. Liu et al. in 'Design of a Self-Tuning PI Controller for a STATCOM Using Particle Swarm Optimization' suggested a self-tuning PI controller for STATCOM in which controller gains are adapted using PSO technique. Based on the estimated system load, a PSO algorithm, which takes the best particle gains, the best global gains, and previous change of gains into account, is employed to reach the desired controller gains. Results of self-tuned PI controller are compared with fixed gain PI controller [3].
D. Maiti et al. in their paper 'Tuning PID and PI □□D□□Controllers using the Integral Time Absolute Error Criterion' proposed application of PSO to the problem of designing a fractional order PID (PI □□D□) controller comprising integral order□, derivative order along with ITAE minimization criterion. The digital realization of the deigned system utilizes the Tustin operator-based continued fraction expansion scheme. This paper also attempts to study the behavior of fractional PID controller vis-à-vis that of its integer-order counterpart and demonstrates the superiority of the former to the latter. [4]
C. M. Lin et al. in their research paper 'Robust PID control system design for chaotic systems using particle swarm optimization algorithm' proposed Robust PID (RPID) control system for chaotic systems comprising a self-tuning PID (SPID) controller. The gradient descent method and H∞ control technique are utilized to derive the on-line tuning laws of SPID controller and the robust controller, so that the robust tracking performance of the system can be yielded. In order to achieve the best solution for SPID controller, the particle swarm optimization (PSO) algorithm is adopted to select the optimal learning rates of SPID controller. A robust controller is discussed in this paper and PSO is used achieve best solution resulting in favorable tracking performance. [5]
W.W. Cai et al. worked on 'Design and simulation of intelligent PID controller based on particle swarm optimization' and proposed an Intelligent PID control method in this paper in which the different parameters are controlled using size of system error and PSO algorithm is used to tune this PID further. According to the size of the system error, this algorithm controls the system with different subsections of different parameters, by using the particle swarm optimization (PSO) to optimize the parameters of the PID controller to solve the problems, such as lag, time-variety and non-linearity. A group of parameters of the PID controller that minimize the evaluation function is calculated rapidly by searching in the given controller parameters area. This method is better than PID optimized by PSO for 1st and 2nd order system with time delay [6].
Y. Bo et al. research paper 'A New PSO-PID Tuning Method for Time-delay Processes' suggested a method in which a relation is developed between coefficients of corresponding powers of s in the numerator and those in denominator of the closed loop transfer function for FOPTD process by using PSO algorithm. The proposed method originates from processes with small time delay; however, it is still effective even if the time delay is quite large. The results show that the proposed method gives significantly better dynamic performances than IMC-PID method [7].

In paper of A. A. El-Gammal et al. titled 'A Modified Design of PID Controller for DC Motor Drives Using Particle Swarm Optimization PSO', PID controller is made adaptive by using PSO algorithm by adjustment of gains to obtain minimum IAE between speed demand and output response. The new technique converts all objective functions to a single objective function by deriving a single aggregate objective function using specified or selected weighting factors. The weighting factors are also treated as dynamic optimization parameters within PSO. Experimental results show that the performance of the optimal PID controller is better than that of the traditional PID controller [8].

In research paper of V. Rajinikanth et al. titled 'I-PD Controller Tuning for Unstable System using Bacterial Foraging Algorithm: A study based on various Error Criterion '; a novel method to tune the I-PD controller structure for the time-delayed unstable process (TDUP) using Bacterial Foraging Optimization (BFO) algorithm is proposed. The tuning process is focused to search the optimal controller parameters Kp, Ki , Kd by minimizing the multiple objective performance criterion. The results shows that the tuning approach is a model independent approach and provides enhanced performance for the set point tracking with improves time domain specifications [9].

E. Salim Ali et al. worked on 'Optimal PID Tuning for Load Frequency Control Using Bacteria Foraging Optimization Algorithm' and proposed a BFOA based Load Frequency Control (LFC) for the suppression of oscillations in power system. A two area non reheat thermal system is equipped with PID controllers. BFOA is employed to search for optimal controllers' parameters to minimize certain performance index. The performance of the proposed controllers has been evaluated with the performance of the conventional integral (I) controller in order to demonstrate the superior efficiency of the proposed BFOA in tuning PID controllers [10].
T. Jain et al. worked on 'Optimization of PD-PI Controller Using Swarm Intelligence'. In this paper, the idea of model generation and optimization is explored for PD- PI controller. Most commonly known, the highly nonlinear Inverted Pendulum system is used as a test system for this approach. A comparison between Evolutionary Algorithms namely GAs (Genetic Algorithms), and Swarm Intelligence, i.e., PSO (Particle Swarm Optimization) and BG (Bacterial Foraging) has been carried out on the basis of performance indices: ITAE (Integral Time Absolute Error), ISE (Integral Square Error), IAE (Integral Absolute Error) and MSE (Mean Square Error) and settling time. The simulations are tabulated in section IV to analyze which technique gives promising results for the system. [11].
In the research work of D. H. Kim et al. titled 'A Biologically Inspired Intelligent PID Controller Tuning for AVR Systems'; a hybrid approach involving Genetic Algorithm (GA) and Bacterial Foraging (BF) for tuning the PID controller of an AVR is proposed. The proposed method is first illustrated using four test functions and the performance of the algorithm is studied with an emphasis on mutation, crossover, variation of step sizes, chemotactic steps, and the life time of the bacteria [12].

3. THE PARTICLE SWARM OPTIMIZATION CONCEPT

Particle swarm optimization is like a genetic algorithm [57] in that the system is initialized with a population of random solutions. It is unlike a genetic algorithm, however, in that each potential solution is also assigned a randomized velocity, and the potential solutions, called particles, are then "flown" through hyperspace.
Each particle keeps track of its coordinates in hyperspace which are associated with the best solution (fitness) it has achieved so far. (The value of that fitness is also stored.) This value is called pbest. Another "best" value is also tracked. The "global" version of the particle swarm optimizer keeps track of the overall best value, and its location, obtained thus far by any particle in the population; this is called gbest. The particle swarm optimization concept consists of, at each time step, changing the velocity (accelerating) of each particle toward its pbest and gbest (global version). Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward pbest and gbest.

3.1 List of Symbols
n: Dimension of the search space
N: Number of Particles in the swarm X: Position of the swarm
V: Velocity of the swarm
S: Search space
Xid(t): Position of the ith particles at time t is an n-dimensional space
Vid(t): Velocity of the ith particles at time t is an n-dimensional space Pid(t): Current best position of the ith particles at time t is an n- dimensional space
Pgb(t): Current global best position of the swarm at time t is an n- dimensional space
w: Inertia weight factor
wmax: Maximum value of inertia weight factor wmin: Minimum value of inertia weight factor C1: Accelerating factor of cognitive components C2: Accelerating factor of social components
c1i : Initial value of accelerating factor of C1
c1f : Final value of accelerating factor of C1
c2i : Initial value of accelerating factor of C2
c2f : Final value of accelerating factor of C2
r1, r2: Random numbers max
Vd : Maximum velocity limit
K: Constriction factor
r: Random number k: current iteration
kmax: Maximum number of iterations
3.2 Mathematical Formulation Of PSO

In PSO algorithms, each particle moves with an adaptable velocity within the regions of decision space and retains a memory of the best position it ever encountered. The best position ever attains by each particle of the swarm is communicated to all other particles. The conventional PSO assumes an n- dimensional search space S , where n is the number of decision variables in the optimization problem, and a swarm consisting of N particles.

In PSO, a number of particles form a swarm that evolves or flies throughout the problem hyperspace to search for optimal or near-optimal solution. The coordinates of each particle represent a possible solution with two vectors associated with it, the position X and velocity V vectors. During their search, particles interact with each others in a certain way to optimize their search experience. There are different variants of the particle swarm paradigms, but the most general one is the Pgb model, where the whole population is considered as a single neighborhood throughout the optimization process. In each iteration, the particle with the best solution shares its position coordinates Pgb information with the rest of the swarm.

Thus the variables are defined as follows.

The position of the ith particle at time t is an n-dimensional vector denoted

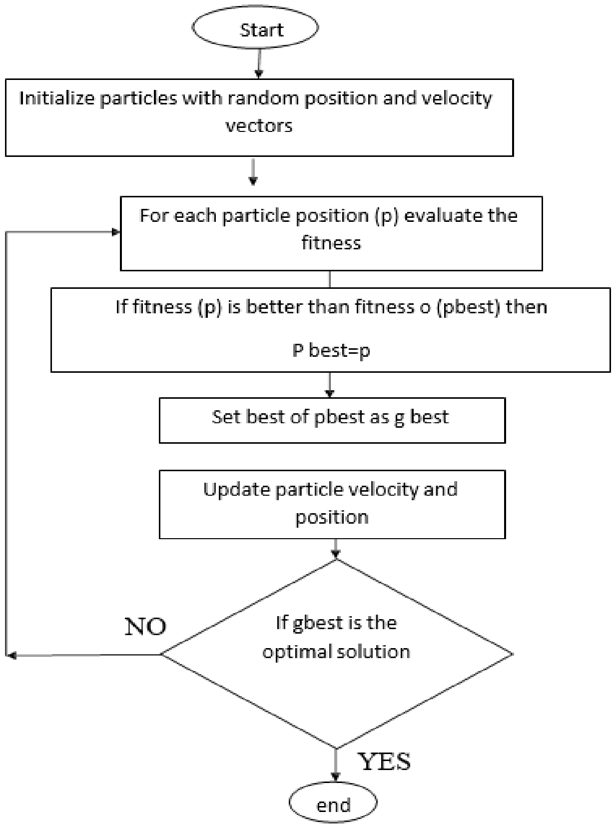
3.3 The Psedudo-Code Of The PSO

Set parameters m, n, w, c1, c2;
Initialize particles for xi and vi, i=1,2,......,m; Evaluate xi, i=1,2,....,m;
Find pg and set pi=xi; Do
For i=1 to m { For d=1 to n }
Updating velocity using equation (2.8);
Updating position using equation (2.9),(2.10),(2.11);}
If f(xi) < f(pi) then pi=xi; If f(xi) < f(pg) then pg=xi;}
Until stopping criteria is met; Output the best solution; End

3.4 BASIC PSO ALGORITHM FOR CONSTRAINED PROBLEM

- Defined the problem space and set the boundaries
- Initialize an array of particles with random position and velocities inside the space.
- Evaluated the desired objective function (for example minimization) for each particle and compare evaluation with particles previous best values: if the current value is less than the previous best value, then set the best value to the current value.
- Determine the current global minimum among the particle's best positions.
- Compare the global position to the previous global. If current global position is less than the previous global position; then set global position to current global.
- Change the velocity by using equation (2.8).
- Move the next position.
- Check if the current position is still inside the problem space or not (i.e. constraints are violate or not). If the current position is outside the space; set the position to its best value within the space and return to step 3.
- Repeat steps 2-8 all individuals cluster around the optimal solution.
- Stopping criteria:
- When the current iteration is equal maximum iteration.
- When the gradient of g-best value is less than equal to tolerance (1e-8).
- When the standard deviation of the fitness is less than equal to tolerance (1e-8)

3.5 FLOW CHART



4. ARTIFICIAL NEURAL NETWORK AND PSO

An artificial neural network (ANN) is an analysis paradigm that is a simple model of the brain and the back-propagation algorithm is the one of the most popular methods to train the artificial neural network. Recently there have been significant research efforts to apply evolutionary computation (EC) techniques for the purposes of evolving one or more aspects of artificial neural networks.

Evolutionary computation methodologies have been applied to three main attributes of neural networks: network connection weights, network architecture (network topology, transfer function), and network learning algorithms.

Most of the work involving the evolution of ANN has focused on the network weights and topological structure. Usually the weights and/or topological structure are encoded as a chromosome in GA. The selection of fitness function depends on the research goals. For a classification problem, the rate of misclassified patterns can be viewed as the fitness value. The advantage of the EC is that EC can be used in cases with non-differentiable PE transfer functions and no gradient information available.

The disadvantages are

- The performance is not competitive in some problems.
- Representation of the weights is difficult and the genetic operators have to be carefully selected or developed.

There are several papers reported using PSO to replace the back-propagation learning algorithm in ANN in the past several years. It showed PSO is a promising method to train ANN. It is faster and gets better results in most cases.

5. CONCLUSION

This paper presents a small review of the optimization techniques which are used to regulate an objective function to get best outputs with a large stability limit. The base system of all the papers studied is the Power system model using a transfer function on which controller is the conventional type PID controller.in recent years authors have provided the understanding and Implementation of PSO algorithms and Artificial intelligence to tune any system parameters for the outputs. Hence this review paper covers the work of modelling a system in the first part and control techniques with the PSO implementation in the later stages. In this paper majorly PSO is Discussed for the Implementation on Two area Power system in MATLAB software further.

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