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Cuckoo Search algorithm based load frequency controller design for nonlinear interconnected power system

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ABSTRACT

A new optimization technique called Cuckoo Search (CS) algorithm for optimum tuning of PI controllers for Load Frequency Control (LFC) is suggested in this paper. A time domain based-objective function is established to robustly tune the parameters of PI-based LFC which is solved by the CS algorithm to attain the most optimistic results. A three-area interconnected system is investigated as a test system under various loading conditions where system nonlinearities are taken into account to confirm the effectiveness of the suggested algorithm. Simulation results are introduced to show the enhanced performance of the developed CS based controllers in comparison with Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and conventional integral controller. These results denote that the proposed controllers offer better performance over others in terms of settling times and various indices.

Introduction

In the large scale power systems, LFC plays a serious role. The LFC is aimed to ensure the frequency of each area and the inter area tie line power within tolerable limits to deal with the fluctuation of load demands and system disturbances [1,2]. These important functions are delegated to LFC due to the fact that a well-designed power system should keep voltage and frequency in scheduled range while supplying an acceptable level of power quality [3,4].

Several researches and techniques had been applied to the field of LFC during the last decades. Robust control [5–9], decentralized control [10,11], linear quadratic problem [12], pole placement approach [13,14], variable structure control [15], and state feedback [16], are used to deal with LFC problem design. However, these strategies have many problems which limit their applicability. In an effort to overcome these problems, many researches have used artificial intelligence as Fuzzy Logic Controller (FLC) [17–21] and Artificial Neural Network (ANN) [21–23]. Although these methods are effective in dealing with the nonlinear characteristics of the power system, they have their own problems. For example, ANN suffers from the long training time, the selecting number of layers and the number of neurons in each layer. Also, FLC requests a hard work to catch the efficient signals and it needs fine tuning and simulation before operation.

Another approach is to use Evolutionary Algorithm (EA) techniques. EA is visualized to be very effective to deal with LFC problem due to its ability to treat nonlinear objective functions. Among the EA techniques, GA [24–29], PSO [30–33], Bacteria Foraging [34–38], Artificial Bee Colony [39], and Ant Colony Optimization [40] have attracted the attention in LFC controller design. Although these algorithms appear to be efficient for the design problem, they suffer from slow convergence problem in refined search stage, weak local search ability, which may lead them to get trapped in local minimum solution. A new evolutionary computation algorithm, called CS algorithm has been presented by [41] and further formed newly by [42–44]. In addition, it is simple and population based stochastic optimization algorithm. Moreover, it requires less control parameters to be tuned. Also, it is a compatible optimization tool for power system controller design [45,46].

This paper introduces a modern optimization algorithm called CS for the optimum tuning of PI controller parameters in LFC problem. The motivation behind this research is to ensure and prove the robustness of CS based PI, and to enhance the performance of frequency deviation and tie line power under various loading conditions in presence of system nonlinearities.

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Nomenclature

f the system frequency in Hz,
i subscript referring to area (i = 1, 2, 3)
R_i the regulation constant (Hz/p.u MW) for area i,
T_{gi} the speed governor time constant in second for area i
T_{ti} the turbine time constant in second for area i,
T_{ri} the reheat time constant in second for area i,
K_{ri} the p.u megawatt rating of high pressure stage for area i
T_w the hydro turbine time constant,
K_d, K_p, K_i the electric governor derivative, proportional and integral gains, respectively
T_{Pi}, K_{Pi} the time constant and gain of power system respectively for area i
$\Delta Ptie_i$ the difference between the actual tie-line power and scheduled one
B the biasing factor in pu MW/Hz
K_{PPi}, K_{Ili} the gains of PI controller of area i
N the number of area in power systems
tsim the simulation time in second
t time in second
T_{ij} synchronizing coefficient
J objective function
U_i the control signal of area i
K_i the controller of area i
$K_{PPi}^{min}, K_{PPi}^{max}$ the lower and the upper limit of proportional gain of area i
$K_{Ili}^{min}, K_{Ili}^{max}$ the lower and the upper limit of Integral gain of area i
P_a the probability to abandon a nest
n number of nests
x_i^t the current solution
x_i^{t+1} a new solution

List of abbreviations
LFC Load Frequency Control
GA Genetic Algorithm
PSO Particle Swarm Optimization
CS Cuckoo Search
FLC Fuzzy Logic Controller
ANN Artificial Neural Network
ANFIS adaptive neuro-fuzzy inference system
PI proportional plus integral
GRC Generation Rate Constraint
ACE Area Control Error
IAE the integral of absolute value of the error
ITAE the integral of the time multiplied absolute value of the error
ISE the integral of square error
ITSE the integral of time multiply square error

Three area power system

The system under study consists of 3 areas of equal sizes. Areas 1 and 2 are reheat thermal systems and area 3 is a hydro system [17]. The detailed designed model of 3 area hydro-thermal power system for load frequency control is shown in Fig. 1. The thermal plant has a single stage reheat steam turbine and the hydro plant is equipped with an electric governor. In this model, nonlinearities

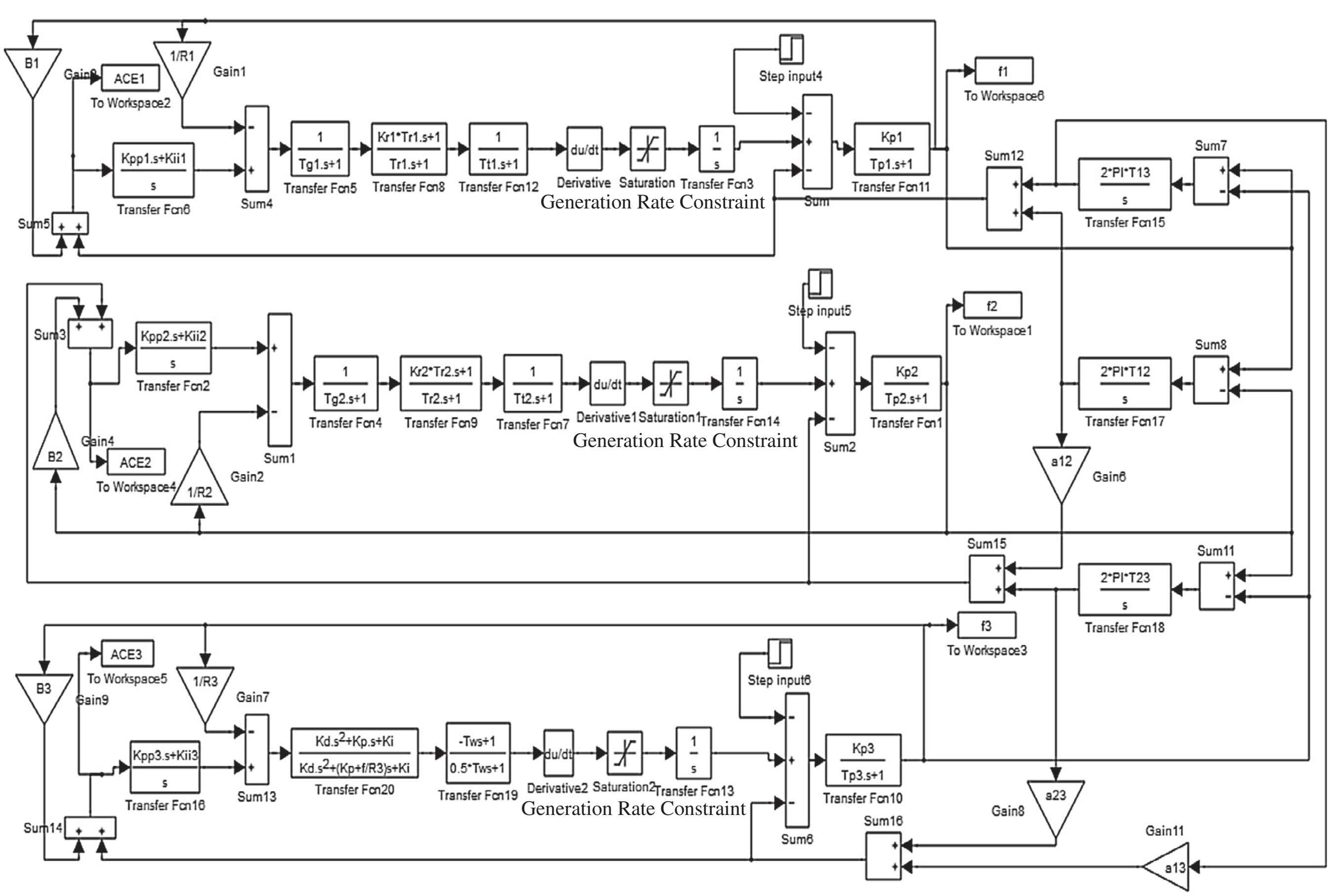

Fig. 1. A three area model.