BAT INSPIRED ALGORITHM BASED INTERVAL TYPE-II FUZZY CONTROLLER FOR LOAD FREQUENCY CONTROL IN SINGLE AREA POWER SYSTEM

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ABSTRACT

BACKGROUND

Load frequency control problem is considered as one of the most important issues in the design and operation of power systems. Due to lack of good efficiency in parameters variation conditions, working conditions of system and nonlinear factors, a simple PI controller is not suitable in industrial applications. Instead, fuzzy controllers can be used in order to enhance the performances of the systems. In this paper, the use of the Bat inspired algorithm based type-II fuzzy controller is proposed to solve the load frequency control problem. To the best of our knowledge, Bat inspired algorithm based type-II fuzzy controller in order to solve load frequency control problem has not been investigated so far. The proposed controller has good performance and is capable to solve the load frequency control problem in conditions of wide variations of system parameters and nonlinear factors such as generation rate constraint. Simulation results show that the proposed controller in this paper exhibits better performance compared to PI controller in damping of system deviations.

KEYWORDS

Load Frequency Control, Single Area Power System, Type-II Fuzzy Controller, Bat Inspired Algorithm.


BACKGROUND

Load-Frequency (L-F) control[1] is an important task in electrical power system design and operation. Since the load demand varies without any prior schedule, the power generation is expected to overcome these variations without any voltage and frequency instabilities. Therefore, voltage and frequency controllers are required to maintain the generated power quality in order to supply constant voltage and frequency to the utility grid.[2] The frequency control is done by load-frequency controllers, which deals with the control of generator loadings depending on the frequency.[3] Many researches have been done and a different approach has been proposed over the past decades regarding the load-frequency control of single and multi-area power systems. The problem of output active power control of a power system in response to power system frequency changes and between regional powers of system lines in a specified range is known as the load-frequency control problem. For optimal performance and optimal operation of power systems, the frequency changes must be maintained within certain limits. Many process control systems such as computers are sensitive to changes in the frequency and their operation is impaired. For such systems, their frequency must be regulated and controlled. Therefore, an adequate supplementary controller to regulate and prevent frequency deviations must be used in the main control centre. The main purpose of designing load-frequency controllers is to ensure the stable and reliable operation of power systems. Since, the components of a power system are nonlinear, a linearised model around an operating point is used in the design process of L-F controllers.

The Principle Roles of LFC for Power Systems are:

1. Maintaining zero steady state errors for frequency deviations.
2. Countering sudden load disturbances.
3. Minimising unscheduled tie-line power flows between neighbouring areas and transient variations in area frequency.
4. Coping up with modelling uncertainties and system nonlinearities within a tolerable region.
5. Guaranteeing ability to perform well under prescribed overshoot and settling time in frequency and tie-line power deviations.

The purpose of load frequency control problem is to maintain a uniform frequency and to adjust and control converted power between areas of the power system in a planned value. In other words, we can say that the aim of load-frequency control problem is keeping the steady-state error of the system on zero. In previous studies on solving the load-frequency control problem, various methods have been used. In the proposed methods, the PI controller is most widely used in industry. The PI controller has a fixed gain that is designed in rated operating conditions and its utilisation is simple, but frequency oscillations can also appear in this case. This means that the PI controller indicates a poor dynamic performance against of system parameters variation and nonlinear conditions such as generation rate constraint. Different types of fixed gain controllers are designed in rated operating conditions while they are unable to achieve performance in practice under many changes in the operating conditions of the system. Any load change in one of the L-F control areas affect the tie-line power flow causing other L-F control areas to generate the required power to damp the power and frequency oscillations. The response time of the L-F controllers is very important to have the power system to gain control with increased stability margins. Therefore, the proposed L-F controller must reduce the response time as well as reducing the magnitude of the oscillations when compared to that of classical types. Thus, a Bat inspired algorithm based
interval type 2 fuzzy controller for tuning PI controller was proposed and the results are compared.

**The Single Area Power System**

The load frequency model of the studied single area power system \[4\] is shown in Figure 1. In solving the load-frequency control problem of the studied system, the generation rate constraint is considered. The nonlinear turbine model considering the generation rate constraint is shown in Figure 2.

![Figure 1. Studied Single Area Power System](image)

![Figure 2. Non-Linear Turbine Model Considering the Generation Rate Constraint](image)

With the main LFC loop, change in the system load will result in a steady state frequency deviation depending on the speed regulation of the governor. To reduce the frequency deviation to zero, we need to provide a reset action by using an integral controller to act on the load reference setting to alter the speed set point. This integral controller would increase the system type by 1, which forces the final frequency deviation to zero. The integral controller gain needs to be adjusted for obtaining satisfactory transient response.\[5\]

**Bat Inspired Algorithm Based Interval Type 2 Fuzzy For Tuning PI Controller**

Bat algorithm is applied for optimising the gains of a proportional plus integral controller for a single area power system. The objective is to obtain the optimum values of the controller parameters, which will minimise the performance index, i.e. objective function, \(J\). The objective function \((J)\) is calculated for initial random set of \(K_p\) and \(K_i\).\[6\] The objective function values are then mapped into a fitness value for each set of \(K_p\) and \(K_i\) in the initial population. After finding the initial fitness of the population, the values are updated based on movement, loudness and pulse rate. These steps are repeated until the values get converged producing optimum \(K_p\) and \(K_i\).

By tuning the gains of the Interval Type-2 Fuzzy PI Controller\(7\) model using Bat algorithm, better results are obtained. Interval Type-2 Fuzzy PI Controller model can be tuned by various methods like changing the scaling factor, modifying the support and spread of membership functions, modifying the rules of the rule base and changing the type of a membership function itself, doing so will result in change of the control surface and hence the output of the Interval Type-2 Fuzzy PI Controller model.\[8\] The usefulness of rule tuning is demonstrated by F. Herrera et al [Herrera et al (1995)]. The rule weights can also be changed to perform a local tuning of linguistic rules, which enables the linguistic fuzzy models to cope with inefficient and/or redundant rules thereby enhancing the robustness, flexibility and system modelling capability. By assigning a rule weight to each of the fuzzy rules, complexity is increased while its accuracy is improved, which suggests a trade-off relation between the accuracy and complexity. If a rule weight is applied to the consequent part of the rule, it modifies the size of the rule’s output value. Parameters like rules, membership functions and rule-weights play an important role in any fuzzy model, and optimising them is a necessary task, since these parameters are always built by designers with trial and error along with their experience or experiments.\[9\]

After performing the tuning of individual parameters, an inference is drawn as to which procedure is better than the other with reference to ISE criterion. The Bat algorithm tuned fuzzy systems are primarily used to automate the knowledge acquisition step in fuzzy system design, a task that is usually accomplished through an interview or observation of a human expert controlling the system.\[10\] An evolutionary algorithm adapts either part or all of the components of the fuzzy knowledge base. Fuzzy knowledge base is not a monolithic structure, but is composed of the database and the rule base where each plays a specific role in the fuzzy reasoning process. Genetic tuning processes are targeted at optimising the performance of an already existing fuzzy system.

Designing a fuzzy rule based system is equivalent to finding the optimal configuration of fuzzy sets and/or rules and in that sense can be regarded as an optimisation problem. The optimisation criterion is the problem to be solved at hand and the search space is the set of parameters that code the membership functions, fuzzy rules and fuzzy rule weights. The Figure 4 represents a Bat algorithm tuned fuzzy system. The performance is aggregated into a scalar fitness value on which basis the evolutionary algorithm selects better adapted chromosomes. A chromosome either codes parameters of membership functions, fuzzy rules and fuzzy rule weights or a combination thereof. By means of crossover and mutation, the evolutionary algorithm generates new parameters for the database and/or rule base whose usefulness is tested in the fuzzy system.

![Figure 3. Bat Algorithm Tuned Fuzzy System](image)

The objective functions considered here is based on the error criterion. In this project, performance of membership functions, rules and weight tuning are evaluated in terms of Integral Square Error (ISE) criteria. The error criterion is given as a measure of performance index.\[11\] The ISEs of individual
parameters are added together to obtain an overall ISE. This is done to simplify the task of Bat algorithm.

The objective of Bat algorithm is to minimise this overall ISE. The overall ISE is given by Equation (1).

\[ISE = \sum_{i=1}^{6} e_i^2(t)dt\]  

(1)

Where \(e_i(t)\) is the error signal for the \(i\)th parameter. Here, \(i\) can take values from 1 to 6 corresponding to 6 parameters.

**SIMULATION RESULTS**

The model of the system under study has been developed in MATLAB/SIMULINK environment \(^{12}\) and Bat algorithm program has been written (in mfile). The developed model is simulated in a separate program (in m file using initial population/controller parameters) considering a 10% step load change in area 1. The objective function is calculated in them file and used in the optimisation algorithm. The process is repeated for each individual in the population. Using the objective function values, the population is modified by Bat algorithm for the next generation.

Simulations were conducted on an Intel, core-2 Duo CPU of 2.4 GHz and 2 GB RAM computer in the MATLAB 7.10.0.499 (R2010a) environment. The optimisation was repeated 10 times and the best final solution among the 20 runs is chosen as proposed controller parameters.

**CONCLUSIONS**

In this paper, the Bat inspired algorithm based type-2 fuzzy logic controller was proposed to solve the load frequency control problem of single area power system. Tuning of controller parameters is essential for achieving good response with minimum error or disturbance while designing load frequency controllers for single area power systems. This design takes advantage of the superior characteristics inherent PI controller and dual mode concept of the search ability of Bat inspired algorithm based type II fuzzy logic controller. An Integral square error of the frequency deviation is taken as the objective function to improve the system response in terms of settling time and overshoot. Simulation results show that the proposed controller in damping of frequency deviations of power system has a better performance than the PI controller. Simulation results emphasise the effectiveness of the proposed algorithm. Besides simple architecture of the proposed algorithm, it has the potentiality to implement in real time applications.
REFERENCES