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Multi-stage fuzzy load frequency control using PSO

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ABSTRACT

In this paper, a particle swarm optimization (PSO) based multi-stage fuzzy (PSOMSF) controller is proposed for solution of the load frequency control (LFC) problem in a restructured power system that operate under deregulation based on the bilateral policy scheme. In this strategy the control is tuned on line from the knowledge base and fuzzy inference, which request fewer sources and has two rule base sets. In the proposed method, for achieving the desired level of robust performance, exact tuning of membership functions is very important. Thus, to reduce the design effort and find a better fuzzy system control, membership functions are designed automatically by PSO algorithm, that has a strong ability to find the most optimistic results. The motivation for using the PSO technique is to reduce fuzzy system effort and take large parametric uncertainties into account. This newly developed control strategy combines the advantage of PSO and fuzzy system control techniques and leads to a flexible controller with simple stricture that is easy to implement. The proposed PSO based MSF (PSOMSF) controller is tested on a three-area restructured power system under different operating conditions and contract variations. The results of the proposed PSOMSF controller are compared with genetic algorithm based multi-stage fuzzy (GAMSF) control through some performance indices to illustrate its robust performance for a wide range of system parameters and load changes.

1. Introduction

Global analysis of the power system markets shows that the frequency control is one of the most profitable ancillary services at these systems. This service is related to the short-term balance of energy and frequency of the power systems. The most common methods used to accomplish frequency control are generator governor response (primary frequency regulation) and load frequency control (LFC). The goal of LFC is to reestablish primary frequency regulation capacity, return the frequency to its nominal value and minimize unscheduled tie-line power flows between neighboring control areas. From the mechanisms used to manage the provision this service in ancillary markets, the bilateral contracts or competitive offers stand out [1].

During the past decade, several proposed LFC scenarios have been attempted to adapt traditional LFC schemes to the change of environment in the power systems under deregulation [2–4]. In a power system, each control area contains different kinds of uncertainties and various disturbances due to increased complexity, system modeling errors and changing power system structure. As a result, a fixed controller based on classical theory is not certainly suitable for the LFC problem. It is desirable that a flexible controller be developed. Efforts have been made to design load frequency controllers with better performance to cope with parameter changes, using various adaptive neural networks and robust methods [5–10]. The proposed methods show good dynamical responses, but robustness in the presence of model dynamical uncertainties and system nonlinearities were not considered. Also, some of them suggest complex state feedback or high order dynamical controllers, which are not practical for industry practices. Recently, some authors proposed fuzzy PID methods to improve performance of the LFC problem [11–13]. It should be pointed out that they require a three-dimensional rule base. This problem makes the design process is more difficult. To overcome this drawback, in author's pervious papers [14,15] a improved control strategy based on fuzzy theory and GA technique have been proposed. The resulting structure is a multi-stage fuzzy (MSF) controller using two-dimensional inference engines (rule base) to perform reasonably the task of a three-dimensional controller. The proposed method requires fewer resources to operate and its role in the system response is more apparent, i.e. it is easier to understand the effect of a two-dimensional controller than a three-dimensional one [14]. In order for a fuzzy rule based control system to perform well, the fuzzy sets must be carefully designed. A major problem plaguing the effective use of this method is the difficulty of accurately constructing the membership functions. Because, it is a computationally expensive combinatorial optimization and also

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extraction of an appropriate set of membership function from the expert may be tedious, time consuming and process specific. Thus, to reduce fuzzy system effort cost, in our pervious paper [15] a GA technique based on the hill climbing method have been proposed. Although, GA seems to be good methods to solve optimization problems, when applied to problems consisting of more number of local optima, the solution from GA are just near global optimum areas. Also, it takes long simulation time to obtain the solution. Moreover, when the number of parameter is more, optimization problem is complex and coding chromosomes with more gens for increasing algorithm accuracy is caused GA convergent speed will become very slow, so that convergent accuracy may be influenced by the slow convergent speed. Here, to overcome these drawbacks, a PSO based MSF (PSOMSF) controller is proposed. In this study, PSO technique is used for tuning membership functions of MSF controller. This method is proposed to improve optimization synthesis such that the global optima are guaranteed and the speed of algorithms convergence is extremely improved, too. PSO algorithm can be used to solve many of the same kinds of problems as GA and does not suffer from of GA's difficulties [16–18]. PSO is a novel population based metaheuristic, which utilize the swarm intelligence generated by the cooperation and competition between the particle in a swarm and has emerged as a useful tool for engineering optimization. It has also been found to be robust in solving problems featuring nonlinearing, non-differentiability and high dimensionality. The proposed PSOMSF controller is tested on a three-area restructured power system under different operating conditions in comparison with the GAMSF [15] controller through some performance indices. Results evaluation show that the proposed method achieves good robust performance for wide range of system parameters and load changes in the presence of system nonlinearities and is superior to the other controllers.

2. Generalized LFC model

In the deregulated power systems, the vertically integrated utility no longer exists. However, the common LFC objectives, i.e. restoring the frequency and the net interchanges to their desired values for each control area, still remain. The deregulated power system consists of GENCOs, TRANSCOs and DISCOs with an open access policy. In the new structure, GENCOs may or may not participate in the LFC task and DISCOs have the liberty to contract with any available GENCOs in their own or other areas. Thus, various combinations of possible contracted scenarios between DISCOs and GENCOs are possible. All the transactions have to be cleared by the independent system operator (ISO) or other responsible organizations. In this new environment, it is desirable that a new model for LFC scheme be developed to account for the effects of possible load following contracts on system dynamics.

Based on the idea presented in [19], the concept of an '*augmented generation participation matrix*' (AGPM) to express the possible contracts following is presented here. The AGPM shows the participation factor of a GENCO in the load following contract with a DISCO. The rows and columns of AGPM matrix equal the total number of GENCOs and DISCOs in the overall power system, respectively. Consider the number of GENCOs and DISCOs in area i be n_i and m_i in a large scale power system with N control areas. The structure of AGPM is given by

$$\mathrm{AGPM} = \begin{bmatrix} \mathrm{AGPM}_{11} & \cdots & \mathrm{AGPM}_{1N} \\ \vdots & \ddots & \vdots \\ \mathrm{AGPM}_{N1} & \cdots & \mathrm{AGPM}_{NN} \end{bmatrix} \qquad (1)$$

where,

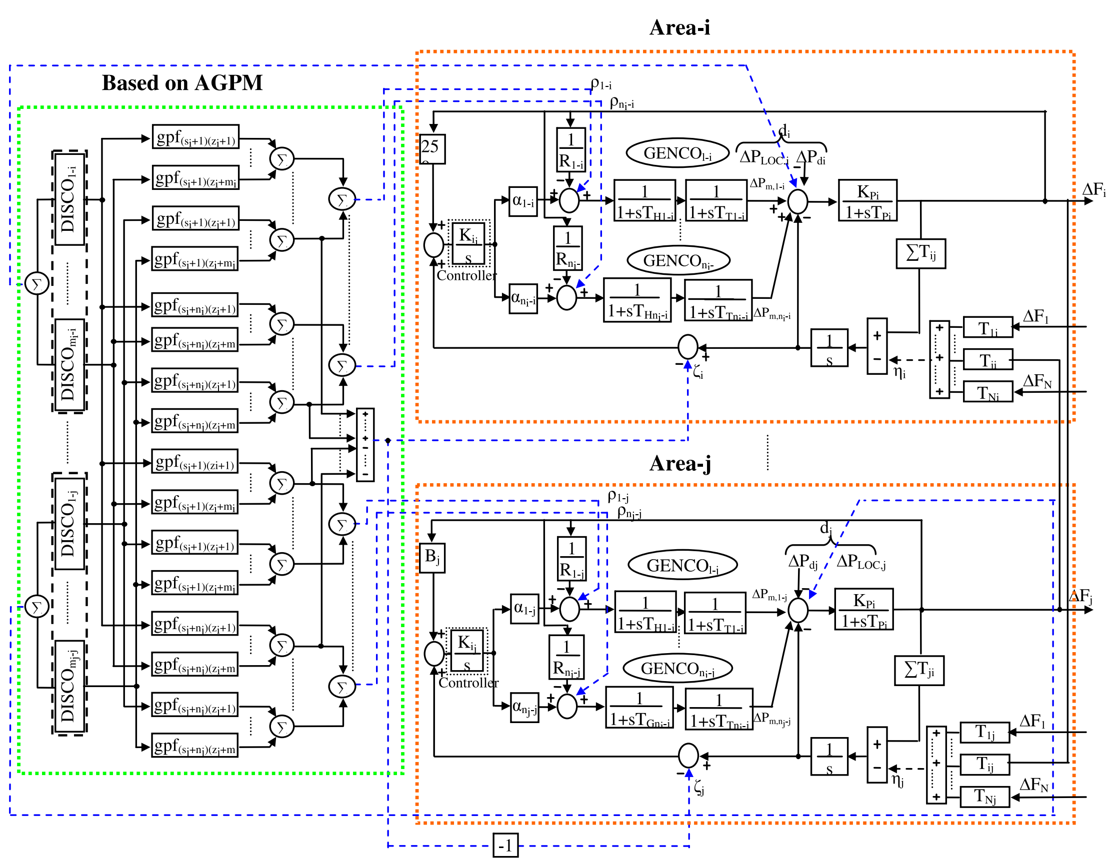

Fig. 1. The generalized LFC scheme in the restructured system.