A Mathematical Study on Genetic Fuzzy Controllers Using Fuzzy Methods and Its Applications

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Abstract

Genetic fuzzy controllers using fuzzy methods and its applications allow researchers to model real-world problems through the development of intelligent and adaptive systems. FGA is a genetic algorithm that uses fuzzy logic-based techniques. The purpose of this composite is to adjust the system parameters to make them robust and optimize the performance of the genetic algorithms. This summary provides basic knowledge of FM and GAS and provides an overview of how these techniques have been cooperatively combined and applied in the real world. Therefore, in this study, GFC are implemented as plausible candidates for automatic generation controller design and application. In GA - fuzzy controllers, genetic algorithms that are based on the foundation of evolutionary inference are used as a global search method for FLC design.

Keywords: *FGA, GA, FM, GAS, GFC etc.*

Introduction

Fuzzy logic is widely used in machine control. The term "fuzzy" refers to the fact that the logic involved may deal with concepts that cannot be expressed as "true" or "false", but rather as "partially true" can go. Although alternative approaches such as genetic algorithms and neural networks can perform as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be put into words that human operators can understand. , so that they can be felt are used in the design of the controller. This makes it easy to mechanize tasks that have already been successfully performed by humans. [1] The automatic output control problem of large interconnected power plants has a long history and dates back to the inception of power systems, where control of frequency was achieved through mechanical means such as synchronous machines (Kumar and Kothari , 2005) wheel governor.
Although the wheel governor has proved to be a very practical means of regulating speed, it suffers from the inability to control frequency after disturbance without supplementary control action. This is also true of modern digital governing systems where good disturbance rejection properties require complementary control action following the frequency event. This has led to a major study known as automatic generation control, which is strongly concerned with frequency control and power regulation on electrical networks and the control of their associated generating units.

Genetic algorithm applications

Genetic algorithms are motivated to provide solutions to real world problems and are based on the process of evolution by natural selection. In particular, genetic algorithms are applied to solve many optimization problems, such as problems where the objective function is discontinuous, non-differentiable, stochastic, or highly non-linear. Genetic algorithms can solve mixed-integer programming problems, where many components are limited to integer-valued (Almeida, Oliveira, & Pinto, 2015).
For example, GA searches through different combinations of materials and designs to find the best combination to achieve the best overall result. Additionally, they are used for designing computer algorithms, scheduling tasks, and solving many optimization problems.

Fuzzy logic

Fuzzy logic provides inference morphology to enable approximate human reasoning abilities to be applied to knowledge-based systems. The traditional approach to knowledge representation lacks a means of representing fuzzy concepts. Fuzzy logic is an approach to computing based on "degrees of truth" rather than the "true or false" (1 or 0) upon which modern computer functions are based. Fuzzy logic includes 0 and 1 as extreme cases of truth, yet also includes different states of truth.

Fuzzy theory

Essential research areas in fuzzy theory are fuzzy sets, fuzzy logic, and fuzzy measurement. Fuzzy Reasoning is an application for knowledge processing of fuzzy logic. Fuzzy systems have the ability to realize a complex non-linear input-output relationship as a synthesis of many simple input-output relationships, similar to neural network functions. This is the essential idea of fuzzy systems and the origin of the word 'fuzzy'. Fuzzy control is an application of fuzzy reasoning for control.

Fuzzy logic controller

A fuzzy logic controller is a system that has a knowledge base, consisting of information provided in the form of linguistic control rules, and a fuzzification interface, which has the effect of turning crisp data into a fuzzy set. Additionally, includes an estimation system that works in conjunction with a knowledge base to provide estimations with the use of a logic method, and a diffusion interface, which converts fuzzy control action to real control action by diffusion method. (Abraham, Hass-Saini, Siari, & Engelbrecht, 2009).

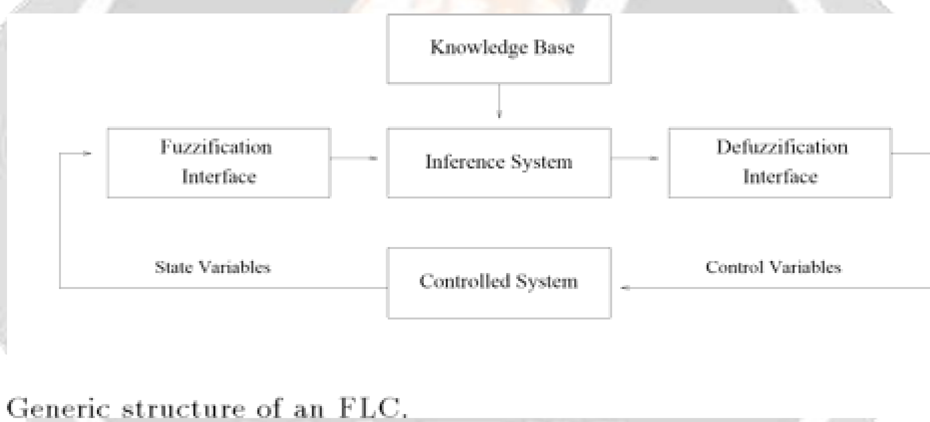

Figure 1.1: Structure of the Fuzzy Logic Controller

Genetic Algorithms for Fuzzy System Identification

Given the high degree of nonlinearity of the output of fuzzy systems, traditional linear optimization tools have their own limitations. Genetic algorithms have demonstrated to be a robust and very powerful tool for performing tasks such as generation of fuzzy rule bases, optimization of fuzzy rule bases, generation of membership functions and tuning of membership functions (Corden et al., 2001a). All of these tasks can be considered as optimization or search processes within large solution spaces (Bastian and Hayashi, 1995) (Yuan and Zhuang, 1996) (Corden et al., 2001b).

Genetic programming for fuzzy system identification

While genetic algorithms are very powerful tools for identifying fuzzy membership functions of a pre-defined rule base, they have limits especially when it comes to identifying the input and output variables of a fuzzy system from a given set of data. Genetic programming has been used to identify input variables, rule bases as well as membership functions comprising a fuzzy model (Bastian, 2000).

Application

Fuzzy control systems are appropriate when the complexity of the process is high, including uncertainty and nonlinear behavior, and no precise mathematical models are available. Successful applications of fuzzy control systems have been reported worldwide with pioneering solutions mainly in Japan since the 80s.

Some of the applications reported in the literature are:

- Air conditioner
- Autofocus systems in cameras
- Household appliances (refrigerator, washing machine...)
- Control and optimization of industrial processes and systems
- Writing system
- Fuel efficiency in engines
- Environment
- Expert system
- Decision tree
- Robotics
- Autonomous vehicle

Result Analysis

GA Fuzzy Controller: AGC Simulation Controller Design

Automatic generation control in the form of a closed loop real time controller where the objective is to ensure that the generation of the control field matches the demand of the load. Not limited to, AGC controls all power generators to minimize frequency variation, first by primary frequency control or speed operation and then by secondary frequency control (or AGC). The latter is comparatively slow compared to primary frequency control, operating on the order of seconds while the AGC responds to frequent frequency deviations over a period of only minutes.

In the context of AGC, PI and PID AGC controllers have been analyzed and described using a classical design approach or more generally trial and error techniques (Khodabakhsian and Edrisi (2008); Sinha et al. (2008); Tan (2009).) and thus the closed-loop performance deteriorates when non-linearity is present and does not provide good dynamic performance over all operating regimes and loading conditions.

Tables 1.1, 1.2 and 1.3 show schematically presented designs of PI and PID type controllers, as applied to the AGC control problem for various closed-loop performance criteria.

Table 1.1: This table shows the nominal PI controller gain optimized via GA

	IAE	ISE	IT AE	IT SE
K_P	0.2229	0.1232	0.0823	0.0185
K_I	0.0559	0.0578	0.0722	0.0991

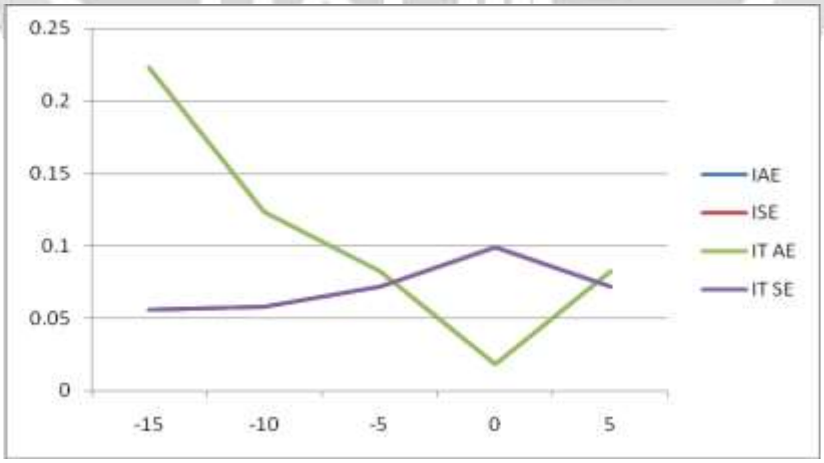

Figure 1.1 (a): ACE feedback with PID controller

This shows that the controller performs well in the midst of non-linearities such as governor deadband (dB) and generation rate constraint (GRC).

Table 1.2: This shows the nominal PID controller gain optimized with GA

	IAE	ISE	IT AE	IT SE
K_P	1.1464	0.1337	1.2444	0.28666
K_I	0.085	0.1235	0.1287	0.0859
K_D	1.3898	1.4869	1.3636	1.3799

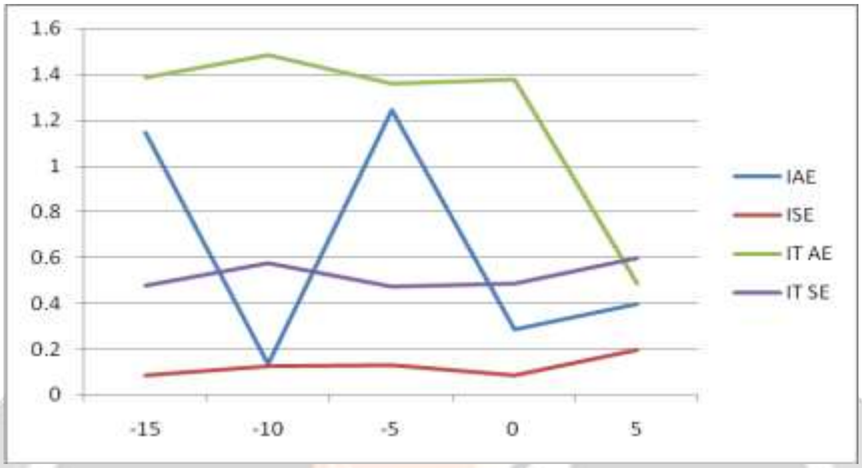

Figure 1.1 (b) ACE rejoinders via PID controller with deadband (DB)

An overview of the performance values is shown in Table 1.3 and compares the transient responses to those displayed in Figure 1.1(a, b, c) and describes the selection of performance criteria. The optimum transient response characteristic for AGC control of interconnected power is represents an important role. (Sinha et al. (2008); Patel (2007)).

Table 1.3: PI and PID types showing performance indices for control laws

	IAE	ISE	IT AE	IT SE
PI	0.3309	0.948	0.0428	0.6861
PID	0.3309	0.948	0.0428	0.8758

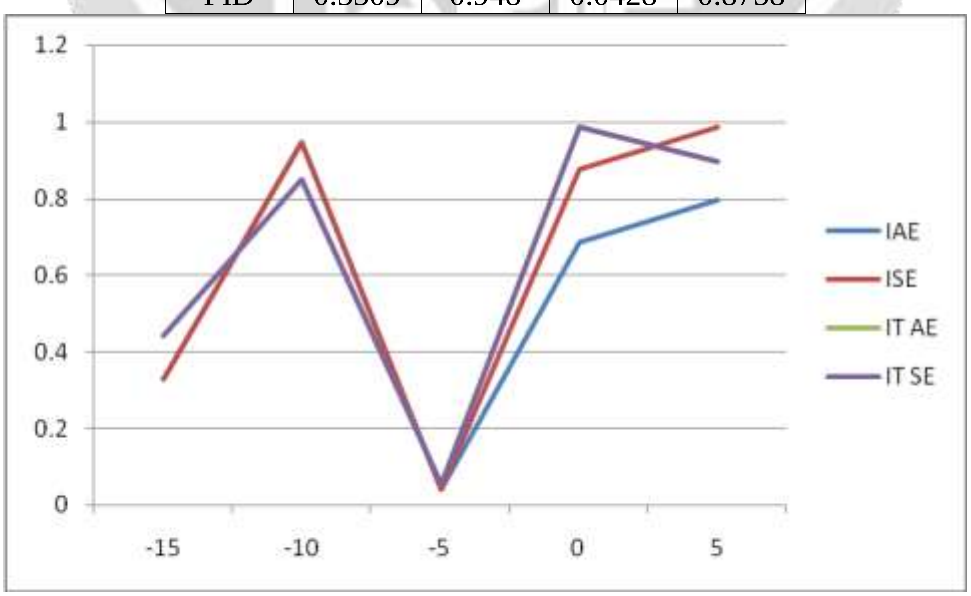

Figure 1.1 (c): With PID controller with ACE feedback and Generation Rate Constraint (GRC)

Figure 1.1 (a, b, c): PI/PID controller recitation to different performance indices by non-linearity's by deadband and generation rate restriction type.

Conclusion

The automatic generation control (AGC) problem of large interconnected power systems is discussed in this paper, in particular the design of AGC controllers and how soft computing can be applied as a viable AGC control strategy under the auspices of GA fuzzy controller design techniques can be done. Thus, the health of network frequencies within the AGC system is the primary indicator of network performance and forms the measure by which system generation performance is analyzed. Since frequency is the principal common factor within an interconnection, any frequency deviation from its specified nominal operating frequency is a measure of network health. Typically the integral of the frequency over time is a measure of performance. The results suggest that fuzzy control rules can be significantly reduced by this encoding mechanism, and hence simplify the search space for controller optimization. The transient performance characteristics are favorable.

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