Research Papers

A FUZZY BASED LOAD FREQUENCY CONTROLLER

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ABSTRACT

A fuzzy logic based load frequency controller model for power systems isdeveloped and simulated in this paper. The proposed simulation model is comparedwith the classical regulating systems in order to verify and show the advantages of the model and controller developed. The design process of the proposed fuzzy logiccontroller is given in detail step by step to show a direct and simple approach for designingfuzzy logic controllers in power systems.
KEY WORDS:*Single area; Fuzzy sets; Fuzzy rules.*

INTRODUCTION

Load-Frequency (L-F) control is an important task inelectrical power system design andoperation. Since the load demand varies without any prior schedule, the power generationis expected to overcome these variations without any voltage and frequency instabilities.Therefore voltage and frequency controllers are required to maintain the generated powerquality in order to supply constant voltage and frequency to the utility grid. The frequencycontrol is done by load-frequency controllers, which deals with the control ofgenerator loadings depending on the frequency. Many research has been done and differentapproaches has been proposed over the past decades regarding the load-frequencycontrol of single and multi area power systems .

The main purpose of designing load-frequency controllers is to ensure the stable and reliableoperation of power systems. Since the components of a power system are non linear,a linearized model around an operating point is used in the design process of L-Fcontrollers. Some of the proposed methods in literature deal with system stability usingfixed local plant models ignoring the changes on some system parameters.Fuzzy set theory provides a methodology that allows modeling of the systems that are

too complex or not well defined by mathematical formulation. Fuzzy logic controllersbased on fuzzy set theory are used to represent the experience and knowledge of a human operator in terms of linguistic variables that are called fuzzy rules. Since an experienced human operator adjusts the system inputs to get a desired output by just looking at the system output without any knowledge on the system's dynamics and interior parameter

variations, the implementation of linguistic fuzzy rules based on the procedures done by human

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operators does not also require a mathematical model of the system. Therefore a fuzzy logic controller (FLC) becomes nonlinear and adaptive in nature having a robust performance under parameter variations with the ability to get desired control actions for complex, uncertain, and nonlinear systems without the requirement of their mathematical models and parameter estimation. Fuzzy logic based controllers provide a mathematical foundation for approximate reasoning, which has been proven to be very successful in a variety of applications [10]. As in many different areas, the use of fuzzy logic controller has been increased rapidly

in power systems, such as in load-frequency control, bus bar voltage regulation, stability, load estimation, power flow analysis, parameter estimation, protection systems, and many other fields. Fuzzy logic applications in power systems are given in [8] with a detailed survey.

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. The results of the classical controller and the fuzzy logic controller are compared, and since the response time of the stabilizer of the load frequency is very important, a quicker an more stable solution is achieved with FL controller than the one found by controlling in a classical way.

THE LOAD-FREQUENCY (L-F) CONTROL

The principle block of the power system studied in this paper is given in Figure 1. Twoparts of this system can be considered. A considerable attention should be pay to the

LFC (Load Frequency Control) section. Changes in real power mainly affect the systemfrequency, while reactive power is less sensitive to changes in frequency and is mainlydependent on changes in voltage magnitude. The LFC thus controls the real power andthe frequency of the system. It also has a major role in the interconnection of differentpower plants [6].

The LFC is used to maintain a reasonable uniform frequency. The first step of controlengineering consists of mathematical modeling. Two methods are well-known: the transferfunction method and the steady state method. Linear systems cannot often be foundin real situations, but a close approximation by linearizing is suitable for simulation. Asimulation model derived here using the transfer function model [6]. The block diagramthat represents the approximation of the real system behaviors is shown in Figure 2. Thisis a small signal model used to represent the influence of load changes.The source of mechanical power, commonly known as the prime mover, may be eitherhydraulic energy or steam. The mathematical model for the turbine relates the changes inmechanical power output ΔPm to changes in steam valve position ΔPV. Both ΔPm and ΔPVare represented by x2 and x1, respectively, in Figure 2. The most simple prime movermodel can be approximated with a single time constant such as the one given by τg in

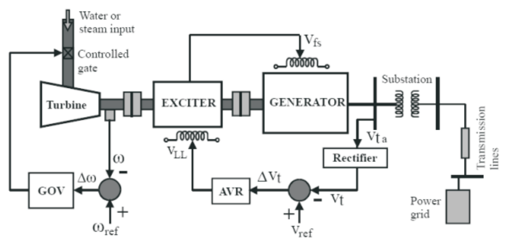

Fig. 1Control Block diagram of Power system

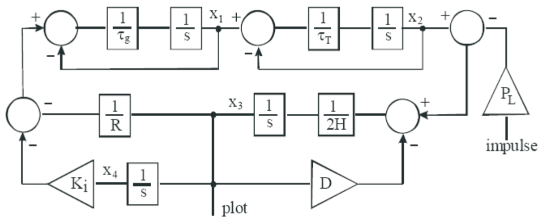

Fig. 2 Simulation block diagram of a single area power system with an integral controller.

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FUZZY LOGIC CONTROLLER

As explained in the introduction, the FLC performs thesame actions as a human operatorby adjusting the input variables, only looking at the system output. The controller consistsof three sections: fuzzifier, rule base and defuzzifier. Thefuzzifier first converts its two input signals, the main signal ($\Delta\omega$ in this case), and the stepchange of every sample $\Delta(\Delta\omega)$, to fuzzy numbers. This numbers are the input of the ruletable, which calculates the fuzzy-number of the controlled output signal by taking theright decisions. Finally this resulting number is converted in the defuzzifier to the crispvalues.

As the classical controller the FLC alsohas an integrating part to be implemented.Therefore the controller has to be designedin such a way that the resultant incrementaloutput $\Delta(\Delta P(k))$ is added to theprevious value $\Delta(\Delta P(k-1)$ to yield the currentoutput $\Delta(\Delta P(k)$. It should be notedthat this is nothing but the digital implementationof an integrator, using Eulerintegration.

FUZZY REASONING

The crisp universes of Δ, Δ (Δ) and Δ (ΔP) have been partitioned into five regions as M, N, O, P and Q as explained earlier. These five regions in all three universes are represented

by triangular fuzzy membership functions defined by (4) and shown in Figure 7 where 'b' is the crisp value with a membership degree of 1 in the corresponding fuzzy set. 'a' and 'c' define the limits of the triangular fuzzy set The universe of , b=-1.5×10-4 for M, b=-0.75×10-4 for N, b=0 for O, b=0.75×10-4 for P, b=1.5×10-4 for Q. A similar, equal-regions and symmetric partition is made for the universes of $\Delta(\Delta)$ and $\Delta(\Delta P)$. In addition to the definition of these triangular functions, it is required to calculate the membership degree of $\Delta(\Delta P)$

$$\mu(x) = \max\left[\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right]$$

the fuzzy membership values of the following active rules at the output space.

R1: If Δ is N and Δ (Δ) is O then Δ (ΔP) is N
R2: If Δ is N and Δ (Δ) is P then Δ (ΔP) is O
R3: If Δ is O and Δ (Δ) is 0 then Δ (ΔP) is O
R4: If Δ is O and Δ (Δ) is P then Δ (ΔP) is P

L-F CONTROL WITH FUZZY LOGIC

The FL controller is placed on the path where the frequency variation, Δ, is fed backgovernor in power system as shown in Figure 3. The steady state matrices for the FLCcan be constructed using Figure 3.Figure 3 is the main simulation diagram of the L-F control scheme to be used with FL controller. As it can be seen from the fact that the system has third order equations with FLC instead of four as it is the case with classical integrator.

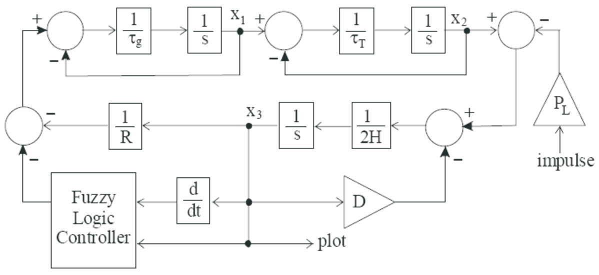

Fig 3. The block diagram of the FL controlled L-F scheme.

Results

Both of the systems, L-F control with classical integral and fuzzy controller, will be simulatedusing the parameter values asô t = 0.5, ô g = 0.2, H = 5, D = 0.8,R= 0.05, Ki = 7, ΔPL = 0.2The resultant graph of the classical system is already shown in Figure 4. The results obtainedby the fuzzy logic controlled system. Both graphics havethe same steady state results: zero. On this point, no improvements can be made. Neverthelessthe settling time and the overshoot can be adjusted. the intervals of the fuzzy sets are thosedescribed and derived from the results of the classical controller given by equation (6).

As expected, the response of the fuzzy logic system with the initial intervals gives similarresults as the classical system. Although, some damping effects with longer settlingtime can also be observed from the response given.By making some adjustments in the intervals, found by using trial-and-error, soon a betterresult is achieved, as shown in Figure 5. The overshoot is almost reduced to zerowith a considerable decrement in settling time.

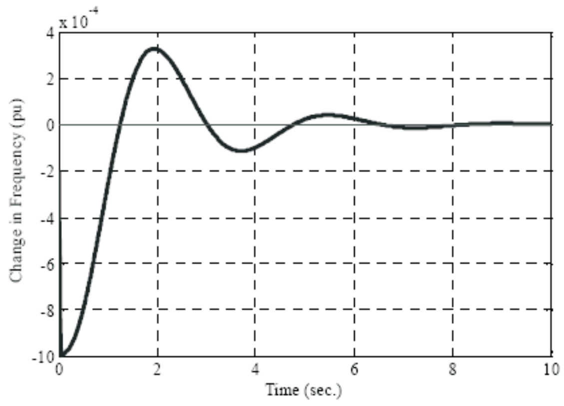

Fig. 4Response of the system with initialintervals of fuzzy sets.

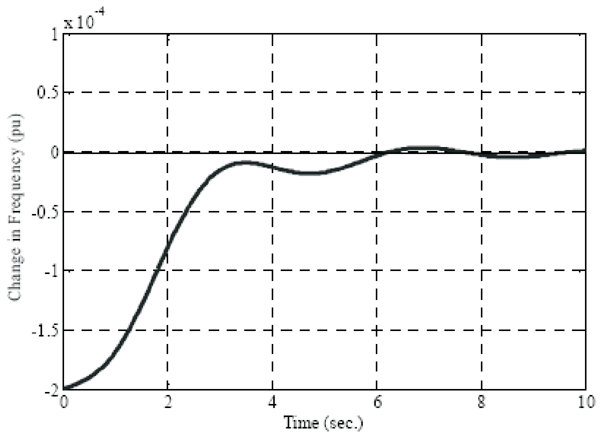

Fig. 5Response of the system withadjusted interval of fuzzy sets.

CONCLUSION

A frequency load controller based on fuzzy logic theory has been designed and comparedwith the classical one, commonly known as the governor system. The results from bothproposed FL based controller and classical methods were obtained for an impulse referenceinput for comparison. The output of the load change was controlled with less overshootand shorter settling time using the fuzzy logic based controller. The same performancecould not be obtained using the other method. And since many expensive electricaldevices are very sensitive to high frequency fluctuations and the FLC restricts the overshoot,it is highly recommended to apply the fuzzy logic controller instead of the classicalone.As the classical methods increase the order of the system's dynamic model due to additionaldelaying terms, the desired results can be reached faster using FL controller. Sincethe response time is very important in control systems, FL controller giving faster timeresponse and better damping performance is also preferred in L-F controller. The simplificationmade by fuzzy logic controller is a cost reduction advantage that is still one ofthe most important industrial decision making elements.

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