

Three Area Power System Load Frequency Control Using Fuzzy Logic Controller

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ABSTRACT

System frequency is one of the most important parameters of a power system. Due to generation-load mismatches, the system frequency can vary over a small range. When the power consumed by loads and overall losses is greater than the generated power, the operating frequency of the system will decrease, resulting in a situation known as the under frequency condition. In some other case, if some of the loads in a system are disconnected from the system suddenly, or lost, it leads to a condition called as the over frequency condition. This condition is characterized by greater input power than the consumed power by the loads. The rest of the loads in the system will absorb the extra power and the generator inertia, leading to an increase in the system frequency. In both the cases, the system frequency fluctuates from the power system's limited frequency range, further leading to tripping off of the substation and further collapsing of the entire system. The paper describes a new method employing a smart meter to monitor and control the power system frequency which changes according to the loading conditions in the system, whether under load condition or overload condition.

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1. INTRODUCTION

Several research and industrial applications concentrated their efforts on providing simple and easy control algorithms to cope with the increasing complexity of the controlled processes/systems. The design method for a controller should enable full flexibility in the modification of the control surface. The systems involved in practice are, in general, complex, time variant with delays, nonlinearities and often with poorly defined dynamics [1].

Consequently, conventional control methodologies based on linear system theory have to simplify/linearize the nonlinear systems before they can be used, but without any guarantee of providing good performance. To control nonlinear systems satisfactorily, nonlinear controllers are often developed. The main difficulty in designing nonlinear controllers is the lack of a general structure. In addition, most linear and nonlinear control solutions developed during the last three decades have been based on precise mathematical models of the systems [2].

Most of those systems are difficult or impossible to be described by conventional control algorithms to cope with the increasing complexity of the controlled processes/systems. The design method for a controller should enable full flexibility in the modification of the control surface. Most of those systems are difficult or impossible to be described by conventional mathematical relations; hence, these model-based design approaches may not provide satisfactory solutions. This motivates the interest in using FLCs are, they

are based on fuzzy logic theory and employ a mode of approximate reasoning that resembles the decision making process of humans [3].

The behavior of a FLC is easily understood by a human expert, as knowledge is expressed by means of intuitive, linguistic rules. In contrast with traditional linear and nonlinear control theory, a FLC is not based on a mathematical model and is widely used to solve problems under uncertain and vague environments, with high nonlinearities. Since their advent, FLCs have been implemented successfully in a variety of applications such as insurance and robotics. Fuzzy logic provides a certain level of artificial intelligence to the conventional PID controllers. Fuzzy PID controllers have self-tuning ability and on-line adaptation to nonlinear, time varying, and uncertain systems. Fuzzy PID controllers provide a promising option for industrial applications with many desirable features [4].

Electrical Power systems are interconnected to provide secure and economical operation. The main objective of automatic generation controller (AGC) is to maintain the balance between the generation and demand of a particular power system. The interconnected power system is typically divided into control areas, with each consisting of one or more power utility companies. Sufficient supply for generation of each connected area to meet the load demand of its customers [5].

In this paper, Fuzzy Logic Controller (FLC) is used. This type of controller adds a pole at origin resulting in system type so reducing the steady state error. System load is never steady using controller these can be controlled. When uncontrolled case more oscillation, negative overshoot be observed but while comparing to conventional type controller PID and propose work result gives better performances of dynamic responses [6].

2. RESEARCH BACKGROUND

The Existing System of Load Flow Control uses conventional controllers such as PID which improves the transient response. A better margin of stability is ensured with PID controller. The PID controller improves steady state error with little or no overshoot. The problem of controlling the real power output of generating units in response to changes in system frequency and tie-line power interchange within specified limits is known as load frequency control (LFC). Objectives of LFC are to provide zero steady-state errors of frequency and tie-line exchange variations, high damping of frequency oscillations and decreasing overshoot of the disturbance so that the system is not too far from the stability. The interconnected power system is typically divided into control areas, with each consisting of one or more power utility companies. Sufficient supply for generation of each connected area to meet the load demand of its customers. The above mentioned objectives are carried successfully in previous works by different authors using PI and PID controllers. In this paper PID-tune controller is used for better frequency responses. This type of controller is used in power system so reducing the steady state error. System load is never steady using this controller these can be controlled. When uncontrolled case more oscillation, negative overshoot be observed but while comparing to conventional type controller PID and propose work result gives better performances of dynamic responses [7].

3. OBJECTIVES

Fuzzy logic controller method is better method of controlling to the complex and unclear model systems. In the literature sources, we can find different kinds of justification for fuzzy systems theory. Human knowledge nowadays becomes increasingly important – we gain it from experiencing the world within which we live and use our ability to reason to create order in the mass of information (i.e., to formulate human knowledge in a systematic manner). Since we are all limited in our ability to perceive the world and to profound reasoning, we find ourselves everywhere confronted by uncertainty which is a result of lack of information (lexical impression, incompleteness), in particular, inaccuracy of measurements. The other limitation factor in our desire for precision is a natural language used for describing/sharing knowledge, communication, etc. We understand core meanings of word and are able to communicate accurately to an acceptable degree, but generally we cannot precisely agree among ourselves on the single word or terms of common sense meaning. In short, natural languages are vague. The main reason for using a fuzzy based controller is because it gives a linear control over the system where it will give a flexible output over a region of control depending upon the membership functions used in the system. Combining the Fuzzy system with Simulink is an important feature from the user's point of view. Once the fuzzy system has been determined, it can be used in Simulink to simulate dynamical systems [8].

This provides the user every powerful tool to investigate behavior of complex systems. Fuzzy rules can be evaluated from the human experience and knowledge about the system. The objective is to set a fuzzy rule which makes the reliable for the industrial process having different degrees of non-linearity's & variation in parameters. In recent years, power systems have more complicated and Non-linear configurations. Many

industrial establishments are affected by operating point variations. Electricity sector and end user are concerned about power quality reliability, efficiency and energy future. There are many reasons about increasing concerns on power quality. The microprocessor based equipment and power electronic devices are more sensitive to power quality. On the other hand, an electric network consists of many interconnected subsystems. If a fault occurs in a subsystem, disturbances and interruptions adversely affecting power quality take place in the power system. Any disharmonies between energy generation and demand cause frequency deviations. Thus, significant frequency deviations lead to system blackouts. Power system loads are usually variable so that controller system must be designed to provide power system quality. Interconnected power systems regulate power flows and frequency by means of an automatic generation control (AGC). AGC is a feedback control system adjusting a generator output power to remain defined frequency [9].

AGC comprises a load frequency control (LFC) loop and an automatic voltage regulator (AVR) loop. LFC system provides generator load control via frequency. Zero steady-state-errors of frequency deviations and optimal transient behavior are objectives of the LFC in a multi-area interconnected power system. So far there are many studies about load frequency control of interconnected power systems. The aim is a design of feedback controller to realize desired power flow and frequency in multi-area power systems [10].

4. LOAD FREQUENCY CONTROL AND MODELLING

If the system is connected to a number of different loads in a power system then the system frequency and speed change with the governor characteristics as the load changes. If it is not required to keep the frequency constant in a system then the operator is not required to change the setting of the generator. But if constant frequency is required the operator can adjust the speed of the turbine by changing the governor characteristic as and when required. If a change in load is taken care by two generating stations running at parallel then the complexity of the system increases [11].

The possibility of sharing the load by two machines is as follow: Suppose there are two generating stations that are connected to each other by tie line. If the change in load is either at A or at B and the generation of A is alone asked to regulate so as to have constant frequency then this kind of regulation is called flat frequency regulation [12].

The other possibility of sharing the load is that both A and B would regulate their generations to maintain the constant frequency. This is called parallel frequency regulation. The third possibility is that the change in the frequency of a particular area is taken care of by the generator of that area thereby the tie-line loading remains the same. This method is known as flat tie-line loading control. In Selective Frequency control each system in a group is takes care of the load changes on its own system and does not aid the other systems on the group for changes outside its own limits [13].

In Tie-line Load-bias control all the power systems in the interconnection aid in regulating frequency regardless of where the frequency change originates. The equipment consists of a master load frequency controller and a tie line recorder measuring the power input on the tie as for the selective frequency control. The error signal i.e. Δf and ΔP_{tie} are amplified, mixed and transformed to real power command signal ΔP_V which is sent to the prime mover to call for an increase in the torque. The prime mover shall bring about a change in the generator output by an amount ΔP_G which will change the values of Δf and ΔP_{tie} within the specified tolerance. The first step to the analysis of the control system is the mathematical modeling of the system's various components and control system techniques [14].

Applying the swing equation of a synchronous machine to small perturbation, we have:

$$\frac{2H}{\omega} \frac{d\Delta\delta}{dt} = \Delta P_m - \Delta P_e$$

Or in terms of small deviation in speed

$$d\Delta \frac{\omega}{dt} = \frac{1}{2H} (\Delta P_m - \Delta P_e)$$

Taking Laplace Transform, we obtain

$$\Delta\Omega(s) = \frac{1}{2Hs} [\Delta P_m(s) - \Delta P_e(s)]$$

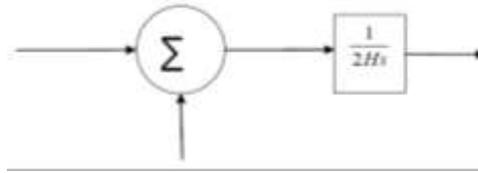


Figure 1. Mathematical modeling block diagram for generator

The load on the power system consists of a variety of electrical drives. The equipment used for lighting purposes are basically resistive in nature and the rotating devices are basically a composite of the resistive and inductive components. The speed-load characteristic is given by

$$\Delta P_e = \Delta P_L + D\Delta\omega$$

Where ΔP_L is the non-frequency- sensitive load change,
 $D\Delta\omega$ is the frequency sensitive load change.
 D is expressed as percent change in load by percent change in frequency.

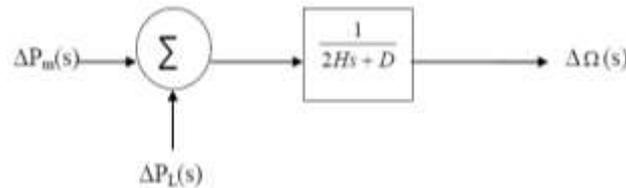


Figure 2. Mathematical modeling block diagram for load

The source of power generation is commonly known as the prime mover. It may be hydraulic turbines at waterfalls, steam turbines whose energy comes from burning of the coal, gas and other fuels. The model for the turbine relates the changes in mechanical power output ΔP_m to the changes in the steam valve position ΔP_v .

$$GT = \frac{\Delta P_m(s)}{\Delta P_v(s)} = \frac{1}{1 + \tau s}$$

Where τ , the turbine constant with the range of 0.2 to 2.0 seconds.

When the electrical load is suddenly increased then the electrical power exceeds the mechanical power input. As a result of this the deficiency of power in the load side is extracted from the rotating energy of the turbine. Due to this reason the kinetic energy of the turbine i.e. the energy stored in the machine is reduced and the governor sends a signal to supply more volumes of water or steam or gas to increase the speed of the prime-mover so as to compensate speed deficiency [15].

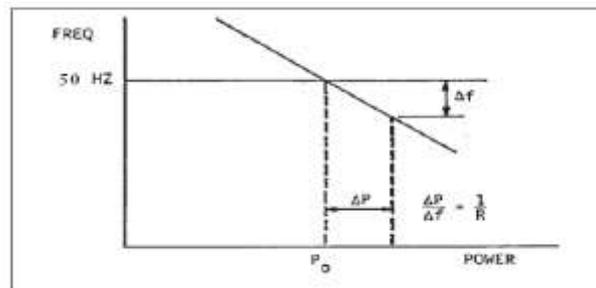


Figure 3. Graphical representation of speed regulation by governor

The slope of the curve represents speed regulation R. Governors typically has speed regulation of 5-6 % from no load to full load.

$$\Delta P_g = \Delta P_{ref} - \frac{1}{R} \Delta f$$

Or in s- domain

$$\Delta P_g(s) = \Delta P_{ref} - \frac{1}{R} \Delta \Omega(s)$$

The command ΔP_g is transformed through hydraulic amplifier to the steam valve position command ΔP_v . We assume a linear relationship and consider simple time constant T_g we have the following s-domain relation:

$$\Delta P_v(s) = \frac{1}{1 + \tau_g s} \Delta P_g(s)$$

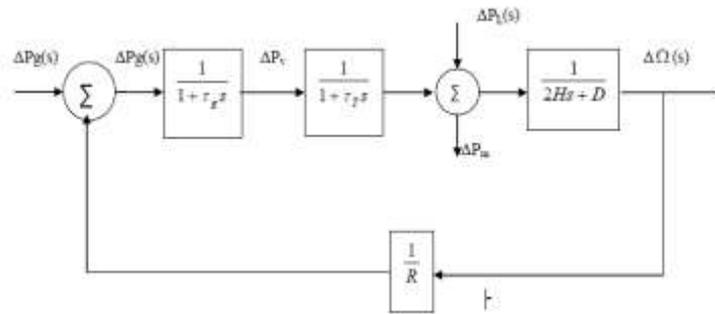


Figure 4. Mathematical modelling of block diagram of single system consisting of generator, load, prime mover and governor

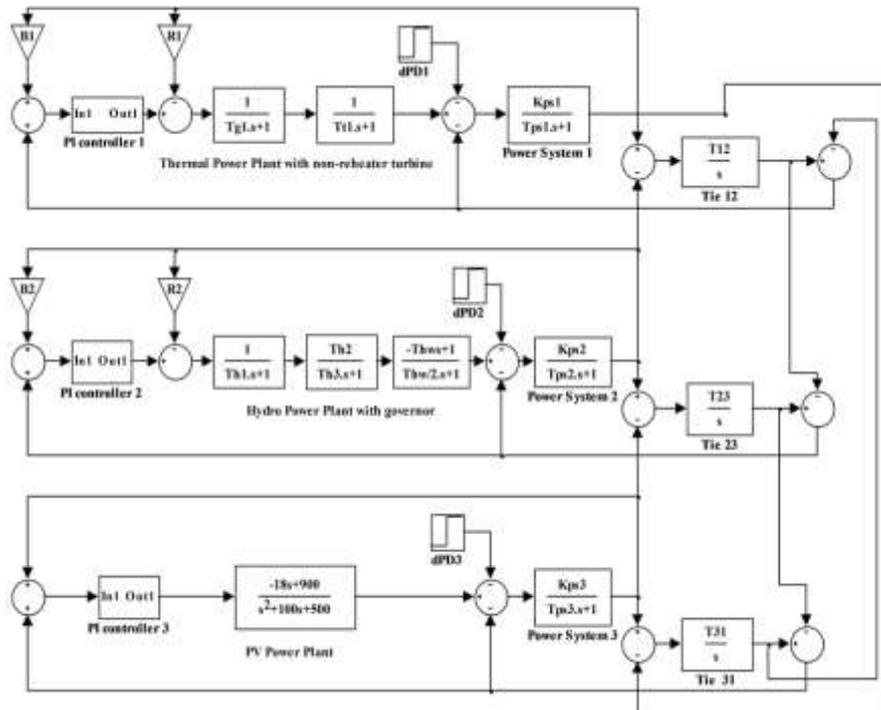


Figure 5. System modelling

The error inputs to the controllers are the respective area control errors (ACE) are:

$$e_1(t) = ACE_1 = B_1 \Delta f_1 + \Delta P_{tie12}$$

$$e_2(t) = ACE_2 = B_2 \Delta f_2 + \Delta P_{tie23}$$

$$e_3(t) = ACE_3 = \Delta f_3 + \Delta P_{tie31}$$

The control inputs of the power system u_1 and u_2 are the outputs of the controllers. The control inputs are obtained as:

$$u_1 = K_{p1} ACE_1 + K_{i1} \int ACE_1$$

$$u_2 = K_{p2} ACE_2 + K_{i2} \int ACE_2$$

$$u_3 = K_{p3} ACE_3 + K_{i3} \int ACE_3$$

5. SIMULATION RESULTS

The Load Frequency Control which is the main theme of the project is implemented with the help of Fuzzy Logic Controller. The membership function which is adopted to take the frequency constant are seven. They are Large Negative (LN), Medium Negative (MN), Small Negative (SN), Very Small (VS), Small Positive (SP), Medium Positive (MP), Large Positive (LP). These membership functions will give a clean explanation that the Fuzzy can operate in many different ways than a ordinary Small and Big. These membership functions are loaded into the Fuzzy Editor which takes the input values. There are two inputs to the Fuzzy Inputs which are Error (E), Change in error (ΔE).

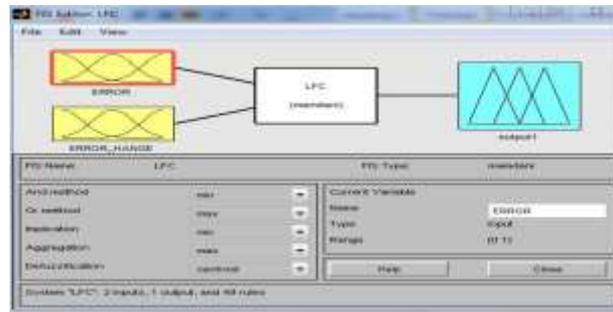


Figure 6. Inputs to the fuzzy editor

The a suitable Fuzzy Rules should be inserted into the fuzzy rule box which will be in the format that “If A is Good and B is Good then Output is Good”.

Table 1. Fuzzy Rule

		Change In Error (Δe)						
		LN	MN	SN	VS	SP	MP	LP
Error (e)	LP	VS	SP	MP	LP	LP	LP	LP
	MP	SN	VS	SP	MP	MP	LP	LP
	SP	MN	SN	VS	SP	SP	MP	LP
	VS	MN	MN	SN	VS	SP	MP	MP
	SN	LN	MN	SN	SN	VS	SP	MP
	MN	LN	LN	MN	MN	SN	VS	SP
	LN	LN	LN	LN	LN	MN	SN	VS

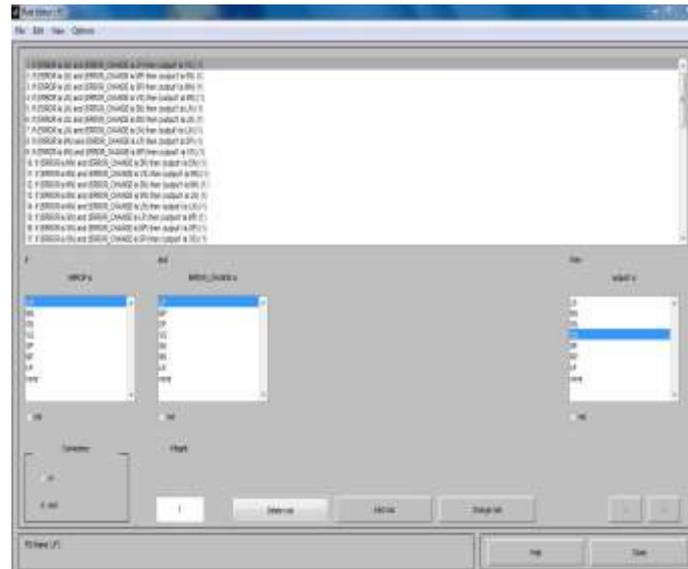
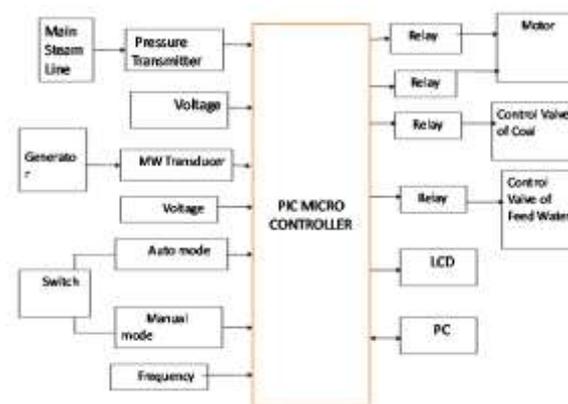


Figure 7. Fuzzy rule base

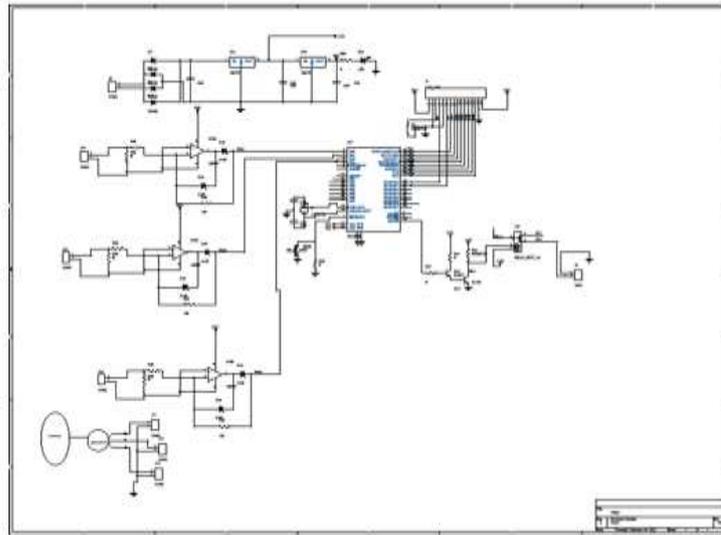
The rules thus entered will be saved as a FIS type of file. This file should be saved in the current folder of Matlab file. This fuzzy file can be entered into the respective fuzzy block with respective denotation. On simulating the respective simulation the following output will be generated which will have advantages of reduction in settling time and also reduction in frequency change when compared to conventional PID controller. By considering the above-stated simulation graphs it could be seen that the system encounters drifts in the frequency succeeding a disturbance in the load and it is primarily because of the mismatch involving the electrical load as well as the mechanical input which is given to the prime mover/turbine. Fluctuations in the system is more in the single area system than two area systems for the reason that all the variations in the load are to be handled by one area only. Moreover variation in frequency is made to be zero by using a secondary loop in both single area in addition to two area systems. We also see that the three area system also operates in a similar manner like that of two area system.

6. HARDWARE RESULTS

Due to generation-load mismatches, the system frequency can vary over a small range. In over frequency and under frequency cases, the system frequency fluctuates from the power system’s limited frequency range, further leading to tripping off of the substation and further collapsing of the entire system. In proposed system, a method to prevent grid from collapsing is being proposed, which employs smart meters to control and monitor the power grid. The Load Frequency is being controlled and monitored for the prevention of grid collapse.



(a)



(b)

Figure 8(a) Block diagram (b) Block diagram connection



Figure 9 (a). Hardware output if all areas are in operation



Figure 9 (b). Hardware output if one area is disconnected and two areas are in OFF condition



Figure 9 (c). Hardware output if one area is disconnected and two areas are in ON condition

7. CONCLUSION

This paper has chiefly investigated on the frequency change as well as change in the tie line power due to the change in the load and also the techniques that may be used for obtaining the optimized values of various parameters for minimizing the changes.

Firstly a secondary control is being introduced for minimizing the deviations in frequency. This is usually vital in case of a single area system or an isolated system as the secondary control loop i.e. an integral controller is generally responsible for reducing the changes in the frequency deviations and maintains the system stability. Therefore without the presence of secondary loop the system loses its stability.

Secondly interconnection of two or more systems is being introduced to cope up with the load changes through tie line power exchange. Interconnecting two or more areas ensures the sharing of the power among the systems during the times of load changes which may occur in any area at any time. Therefore the burden on the controllers to minimize the changes in the frequency is reduced as a result of the rise in the power demand can be fulfilled by drawing power from the neighboring areas and thus maintains the stability of the system.

FURURE SCOPE

- a) Various other optimization algorithmic programs can be used for optimization and the performance can be compared with BF algorithm.
- b) Various controllers may be used to manage the frequency deviations and changes in tie line power.
- c) It may be implemented to system with four areas and also the performance of the system may be studied.

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