Analysis of load frequency control for a distributed grid system involving wind, hydro and thermal power plants using conventional and fuzzy logic controller

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Abstract - *In an electric power system, automatic generation control (AGC) is a system for balancing the power output of multiple generators at different power plants, in response to changes in the load. In an interconnected power system, fluctuations in frequency caused due to load variations and penetration of renewable resources. Load variations occur in either one area or all areas of the system causes change in system frequency and tie line power. Due to high frequency deviation in interconnected power system could result in system collapse. Load frequency control is one of the most efficient method to solve these kinds of problems. In the proposed method a three-area system is considered i.e., area-1 with thermal power plant, area-2 with hydro power plant and area-3 with distributed generation (i.e., wind power plant, solar power plant etc.). In order to analyze the performance of a three-area system, the system responses are comparing the values of undershoot and settling time for each case using conventional control and Fuzzy logic control techniques separately for 1% disturbance in either area. Load frequency control (LFC) including conventional controller is proposed in order to suppress frequency deviations and area control error (ACE) for a power system involving wind, hydro and thermal plants. A three-area system involving thermal plants, a wind farm and a hydro plant will be modeled using MATLAB. The controller performances are simulated using MATLAB/SIMULINK simulation software.*

Key Words: **Load frequency control (LFC), automatic generation control (AGC), area control error (ACE).**

1.INTRODUCTION

The efficient operation of interconnected electrical power systems requires the matching of total generation with total load demand and associated system losses. The operating point of a power system changes, and hence, these systems may cause deviations in nominal power system frequency and scheduled power exchanges to from one area to another area, which may cause undesirable effects. In actual power system operations, the load varies continuously and randomly. The ability of the generation side to track the changing load is limited due to physical / technical consideration, causing imbalance between the actual and the scheduled generation quantities. This action leads to a frequency variation. The difference between the actual and the synchronous frequency causes mal operation of sophisticated equipment's like power converters by producing harmonics. For large scale electric power systems with interconnected areas, Load Frequency Control (LFC) is important to keep the system frequency and the inter-area tie power as near to the scheduled values as possible. The input mechanical power to the generators is used to control the frequency of output electrical power and to maintain the power exchange between the areas as scheduled. [1] A well designed and operated power system must cope with changes in the load and with system disturbances, and it should provide acceptable high level of power quality while maintaining both voltage and frequency within tolerable limits. Load frequency control is basic control mechanism in the power system operation. Whenever there is variation in load demand on a generating unit, there is a momentarily an occurrence of unbalance between real- power input and output. This difference is being supplied by the stored energy of the rotating parts of the unit. [7] Load Frequency Control (LFC) is being used for several years as part of the Automatic Generation Control (AGC) scheme in electric power systems. One of the objectives of AGC is to maintain the system frequency at nominal value (50 Hz).

2.PROBLEM IDENTIFICATION

The developing countries are facing energy crisis continuously in spite of the rapid increases in the power sector. Still there exists a wide gap between the demand and the supply which hampers the overall development.

Today the power engineers including the planners, economists and technologists are worried and thinking the ways to meet these challenges keeping in view the numerous constraints.

The operation of power systems as an interconnected system usually leads to improve system security and economy of operation. In addition, the interconnection permits the utilities to transfer loads to the most economical sources of power. [5].

3. AUTOMATIC GENERATION CONTROL

Automatic generation control (AGC) is defined as, the regulation of power output of controllable generators within a prescribed area in response to change in system frequency, tie- line loading, or a relation of these to each other, so as to maintain the schedules system frequency and / or the established interchange with other areas within predetermined limits. The two basic inter-area regulating responsibilities are as follows:

(i) When system frequency is on schedule, each area is expected automatically to adjust its generation to maintain its net transfer with other areas on schedule, thereby absorbing its own load variations. As long, all areas do so; scheduled system frequencies as well as net interchange schedules for all area are maintained.

(ii) When system frequency is off-schedule, because one or more areas are not fulfilling their regulating responsibilities, other areas are expected automatically to shift their respective net transfer schedules proportionally to the system frequency deviation and in direction to assist the deficient areas and hence restore system frequency.

(iii) The extent of each area's shift of interchange schedule is programmed by its frequency bias setting. Therefore, a control strategy is needed that not only maintains constancy of frequency and desired tie-power flow but also achieves zero steady state error and inadvertent interchange. Numbers of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic performance. [3]

4. REASON FOR THE LIMITS ON FREQUENCY

Dielectric Dissipation Factor (DDF) is also called the speed of the alternating current motors depends on the frequency of the power supply. There are situations where speed consistency is expected to be of high order.

1. The electric clocks are driven by the synchronous motors. The accuracy of the clocks is not only dependent on the frequency but also is an integral of this frequency error.
2. If the normal frequency id 50 Hz and the system frequency falls below 47.5 Hz or goes up above 52.5 Hz then the blades of the turbine are likely to get damaged so as to prevent the stalling of the generator.
3. The under-frequency operation of the power transformer is not desirable. For constant system voltage if the frequency is below the desired level then the normal flux in the core increases. This sustained under frequency operation of the power transformer results in low efficiency and over-heating of the transformer windings.

The most serious effect of subnormal frequency operation is observed in the case of Thermal Power Plants. Due to the subnormal frequency operation the blast of the ID and FD fans in the power stations get reduced and thereby reduce the generation power in the thermal plants. This phenomenon has got a cumulative effect and in turn is able to make complete shutdown of the power plant if proper steps of load shedding technique is not engaged.

5. THREE AREA WIND-HYDRO-THERMAL SYSTEM

Three-area interconnected wind-hydro-thermal system model is shown below:

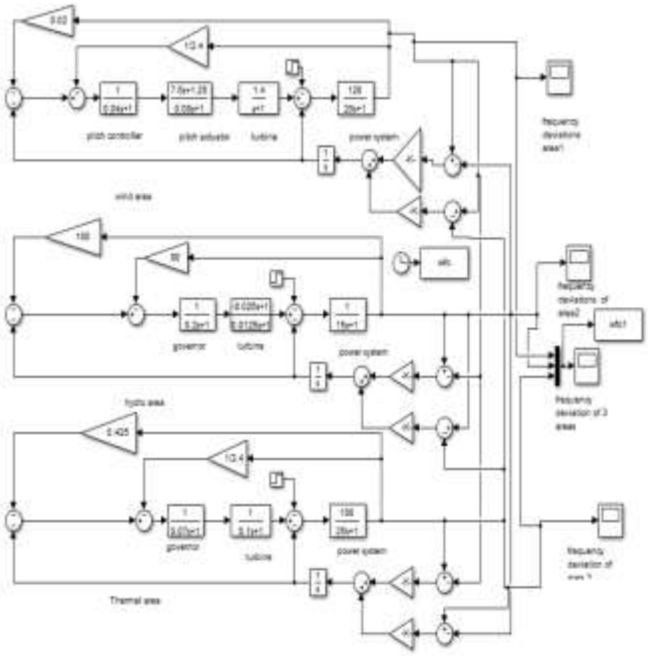


Fig.1. Simulink model of three area wind-hydro- thermal system without controller.

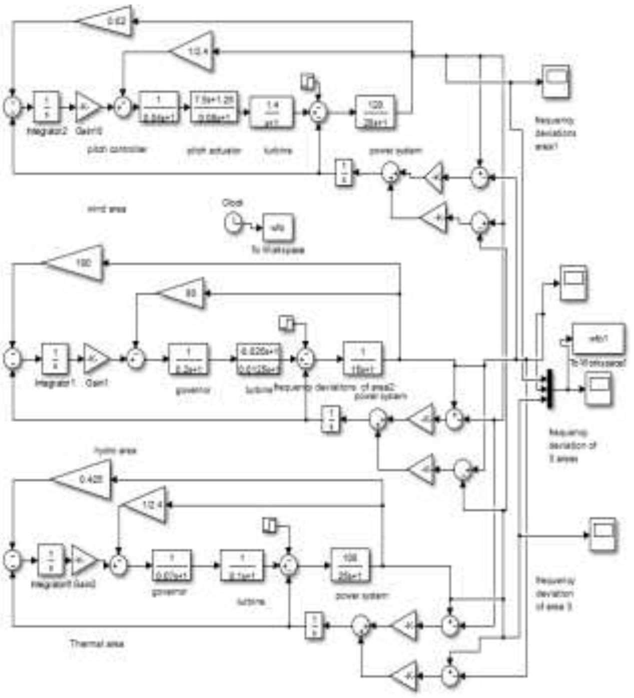


Fig.2. Simulink model of three area wind-hydro-thermal system with controller.

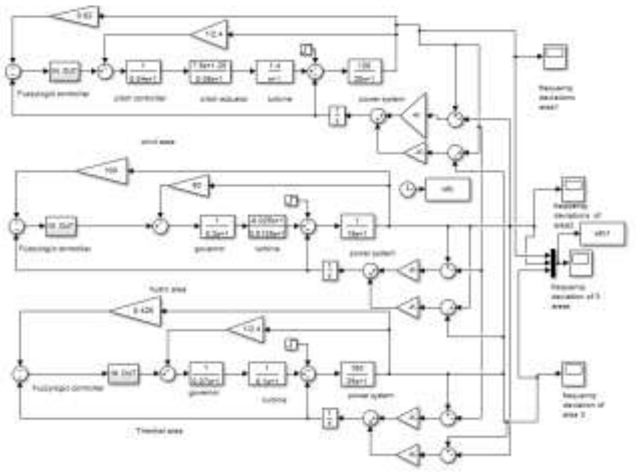


Fig.3. Simulink model of three area wind-hydro-thermal system Fuzzy logic controller.

6. CONTROL STRATEGY

A. Conventional PI Controller

Conventional PI controller is one of the most widespread controllers in the trade industry. The proportional gain offers stability and high frequency response. The steady state error in P controller can be reduced by using the P-I controller. This type of controllers is mainly used where speed parameter is not considered in the system. The integral term insures that the average error is driven to zero. The characteristic of the PI controller is infinite gain at zero frequency. Advantages of PI include that it eliminates forced oscillations the only disadvantage in PI controllers is that it produces excessive overshoot time to a step disturbance.

The PI controller is characterized by the transfer function given below [5]

$$G_C(S) = K_P(1+\frac{1}{sT_i})\text{-----------------}(1)$$

B. Fuzzy logic Controller

The intelligent Fuzzy Logic Controller (FLC) is to fuzzify the controller inputs, and then infer the proper fuzzy control decision based on defined rules. Fuzzy knowledge -based system is shown in Figure. The FLC outputs are produced by defuzzifying this inferred fuzzy control decision [6]. Thus, the FLC processes contain following main components:

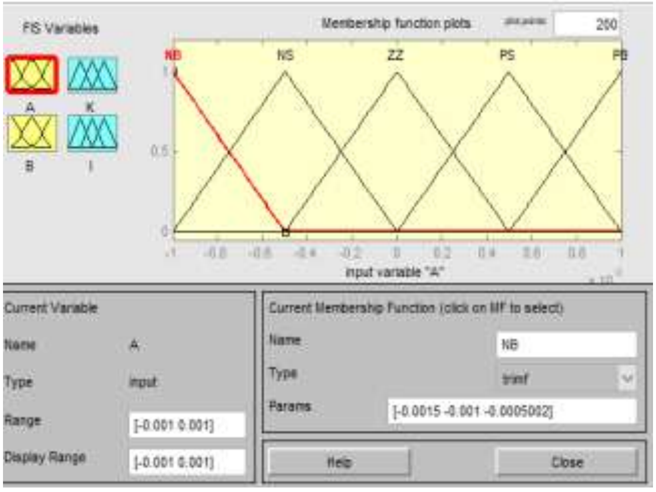
- Fuzzification
  a. Rules Definition
  b. Inference Engine
  c. Defuzzification

C. Rule Base for Fuzzy Logic System

Working of fuzzy logic controller is based on 25 rules. These fuzzy logic rules are in "if and then" format. These rules can be placed in form of table (as in table 1). Here error(A) and cumulative error(B)are two inputs of fuzzy logic controller and Proportional(K) and Integral (I) are two outputs. Fuzzy rule table is given in table-1, input and output membership functions are given in below

Table -1: Rule Base for Fuzzy Logic System

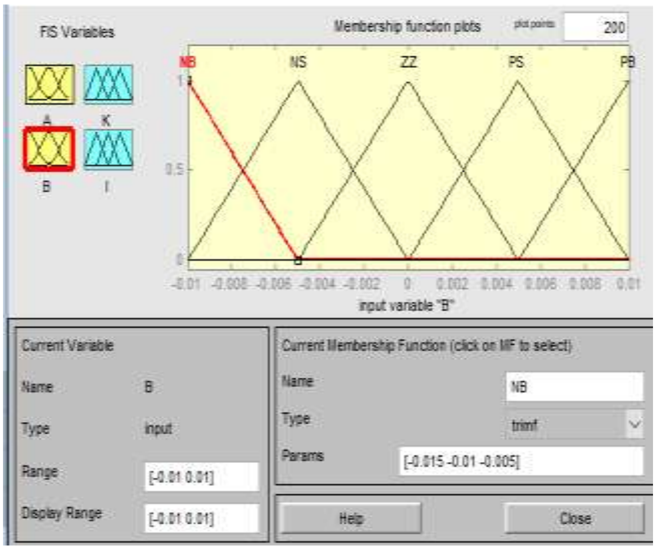
	Input B (Cumulative Error)					
Input A(Error)		NB	NS	ZZ	PS	PB
	NB	S	S	M	B	B
	NS	S	M	M	B	VB
	ZZ	M	M	B	VB	VB
	PS	M	B	VB	VB	VVB
	PB	B	VB	VB	VVB	VVB
	Output (I) Gain					Output (P) Gain



Current Variable
Name A
Type input
Range [-0.001 0.001]
Display Range [-0.001 0.001]

Current Membership Function (click on MF to select)
Name NB
Type trimf
Params [-0.0015 -0.001 -0.0005002]

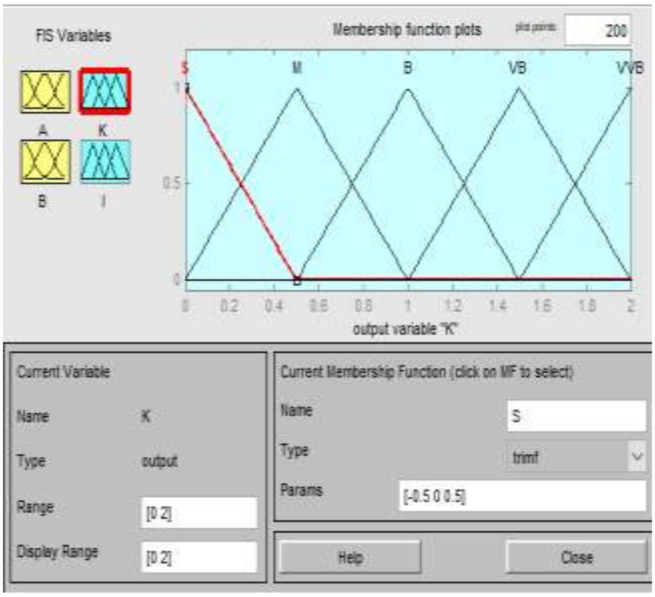
Fig.4. Error Input(A)Membership Function



Current Variable
Name B
Type input
Range [-0.01 0.01]
Display Range [-0.01 0.01]

Current Membership Function (click on MF to select)
Name NB
Type trimf
Params [-0.015 -0.01 -0.005]

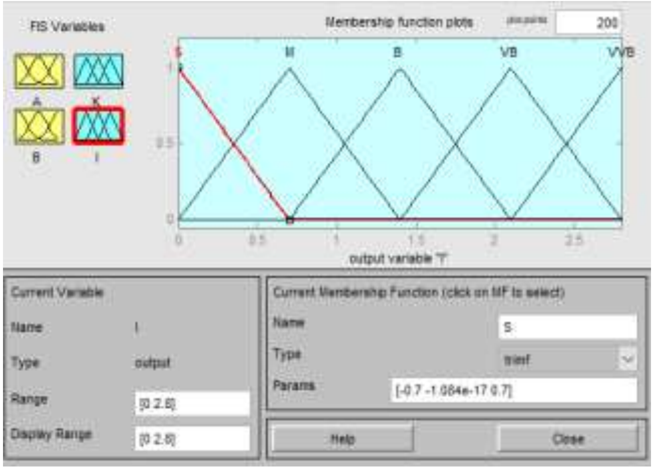
Fig.5.Cumulative Error Input(B)Membership Function



Current Variable
Name K
Type output
Range [0 2]
Display Range [0 2]

Current Membership Function (click on MF to select)
Name S
Type trimf
Params [-0.5 0 0.5]

Fig.6. Proportional Gain Output(K)Membership Function



Current Variable
Name I
Type output
Range [0 2.8]
Display Range [0 2.8]

Current Membership Function (click on MF to select)
Name S
Type trimf
Params [-0.7 -1.084e-17 0.7]

Fig.7. Integral Gain Output(I)Membership Function.

7. SIMULATION RESULTS

The following simulations were performed on three area wind-hydro- thermal systems with namely two controllers i.e., Conventional PI and Intelligent FUZZY LOGIC controller with 1% disturbance in either area

Simulation is carried out in three area system for the following cases

A. Simulated result parameters of three area without controller when subjected 1% disturbance in either area.
B. Simulated result parameters of three area with PI controller when subjected 1% disturbance in either area.
C. Simulated result parameters of three area with Fuzzy logic controller when subjected 1% disturbance in either area.

A. Three Area wind-hydro-Thermal without controller

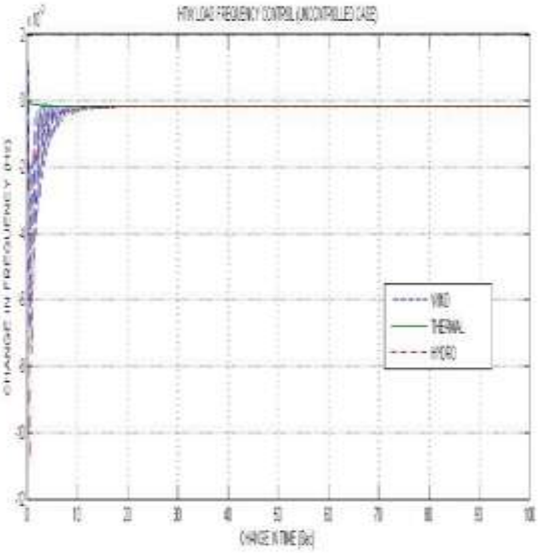


Fig.8. Simulated Result of three area System wind-hydro-Thermal without controller.

B. Three Area wind-hydro-Thermal with PI controller

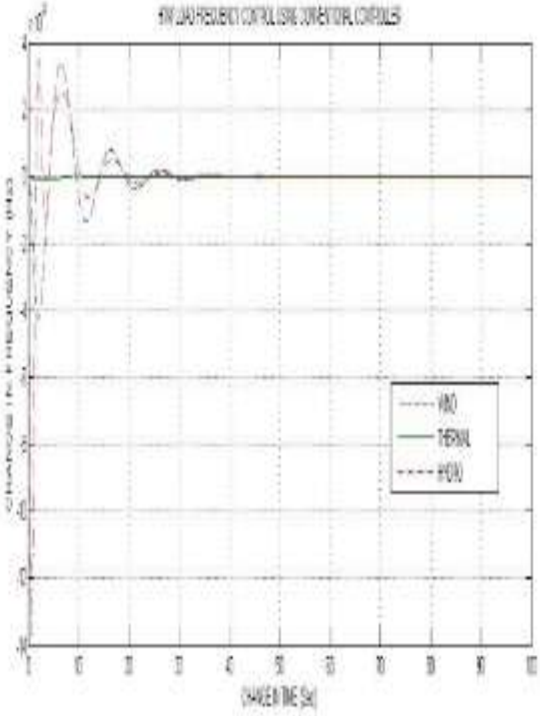


Fig.9. Simulated Result of three area System wind-hydro-Thermal with conventional PI controller.

C. Three Area wind-hydro-Thermal with Fuzzy logic controller

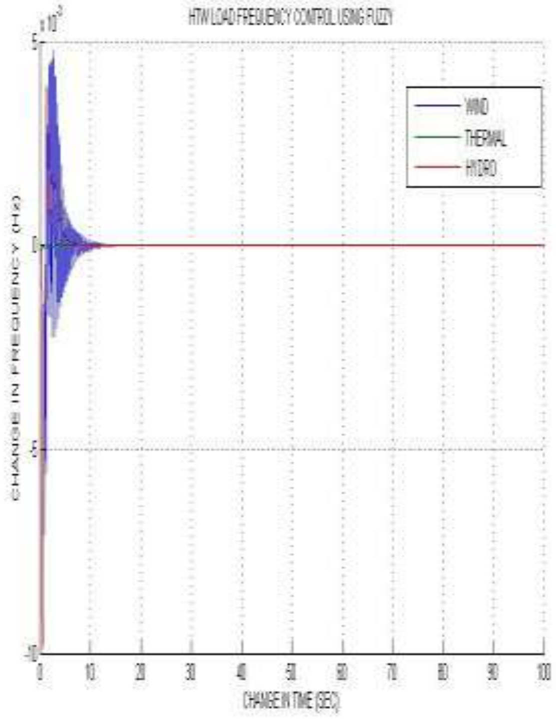


Fig.10. Simulated Result of three area System wind-hydro-Thermal with fuzzy logic controller.

Table 2: Time analysis response of simulations of three area wind-hydro-Thermal following three different cases.

Parameters	System without Controller	System with Conventional Controller	System with Fuzzy Controller
Overshoot (Hz)	0.002	0.001	0.0005
Undershoot (Hz)	0.0014	0.0017	0.009
Settling time (Sec)	Infinite	20	13

8. CONCLUSION

In this paper, three-area thermal, hydro and wind systems have been modeled and these areas are simulated in SIMULINK software. Investigation of three area systems has been done with PI and fuzzy logic controllers. Considering the disturbance as 1%, the result for different controllers are compared and it shows that fuzzy logic controller gives improved dynamic response than PI controller. It is found that fuzzy controller shows the best performance among all conventional controller, in terms of settling time, undershoot, overshoot and minimum oscillations. With the aid of fuzzy controller, the transients in the frequency response reduced to a great extent.

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BIOGRAPHIE

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