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Load Frequency Control for Multi-Area Interconnected Hybrid Power System

Dr. P. Hari Krishnan[1]
Assistant Professor
Department of Electrical and Electronics Engineering
Anna University, Regional Campus-Coimbatore
Tamil Nadu, India

A. Cianna[2]
PG Scholar
Department of Electrical and Electronics Engineering
Anna University, Regional Campus-Coimbatore
Tamil Nadu, India

***Abstract* - Based on intelligent control technique, a new load frequency control (LFC) scheme for three area power systems is introduced. This system is designed to mitigate the frequency and tie-line power deviations of each area. This paper deals with fuzzy algorithm based intelligent technique to analyze the function of non-reheat thermal and hydro units consist of three area interconnected power system. When the sudden disturbance occurs, settling time of the system is high. To overcome this difficulty, intelligent controller is introduced and modeling is carried out in MATLAB /simulink. In this work, the result obtained under the action of intelligent controller and based on the effect of disturbance and settling time the results are compared.**

Index Terms – Fuzzy controller, load frequency control, multi-area, hydro-thermal unit.

I. INTRODUCTION

Power systems consist of generation, transmission and distribution system. The components of the system are generators, transformers, transformers, transformers lines, distribution lines, load and compensating devices like shunt, series and static VAR compensators.

We are generating power using both renewable energy sources and non - renewable energy sources such as tidal, water and solar. The system load keeps changing from time to time in the power system based on the need of the consumers. So properly designed controllers are required to mitigate the frequency deviation and system stability is maintained as well as guarantees its reliable operation.

Load disturbance is occurs due to the continuous variation of loads having lesser values always creates problem for Automatic load frequency control. Because of the variation in the power demand / load in an all area, so it changes the tie-line power flows from the interconnected areas and the frequency of the system and thus the system becomes unstable. So ALFC is to maintain the system stability and load variation. This process is done by maintain tie –line power in addition to minimizing frequency deviation. Inequality load variations involving generation with demand causes frequency deviations.

If the frequency is not maintained within the limited values then it may lead the system collapse and tripping the circuits as well as complete shutdown i.e. blackouts. In power systems, demand power increases and difficulty of electric power systems also increasing.

II. SYSTEM MODELING

A. Governor

It is also known as speed limiter or controller is a device used to measure and regulate the speed of a machine such as an engine. More generally is used to limit the rotational speed of the internal combustion engine or protect the engine from damage due to excessive rotation. If without load reference, whenever the load change occurs, part of the change will be compensated by the valve/gate adjustment. Consequently, the load reference set point can be utilized for adjusting the valve / gate positions to cancel all the variations in load by cancelled the power generation rather than ensuing in frequency deviation.

B. Turbines

The prime mover converts steam energy into mechanical energy. There are two types of steam prime movers one is steam engines and steam turbines. A steam turbine has more advantages over a steam engine as a prime mover i.e. it has simple construction, high efficiency, less floor area requirement higher speed, less floor area requirement and low maintenance cost. Therefore, all modern steam power stations employed steam turbines as prime movers. The transfer function block diagram of thermal power plant with non – reheat turbine and hydro plant is shown in Fig 1, 2.

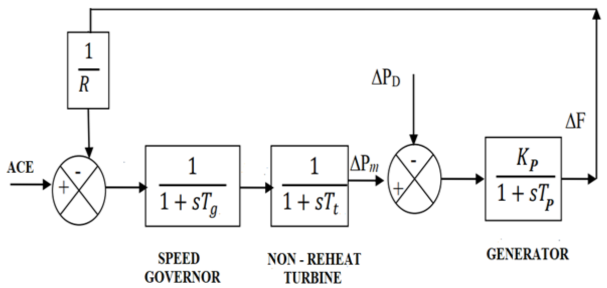


Fig 1. Block diagram of thermal power plant with non – reheat turbine

C. Generator

It is a device that converts mechanical power into electrical power. Based on Faraday's law, this is the most used form for generating electricity. In which mechanical energy forces a generator to rotate due to electrical generation is done using electromagnetic induction. Various types of load on power system consist of electrical devices. Some loads are purely resistive, and others exhibit quite different characteristics. Once a load change occurs, the mechanical power sent from the turbine will no longer match the electrical power generated by the generator. By connecting additional load to the system, the load demand is increased by change in demand.

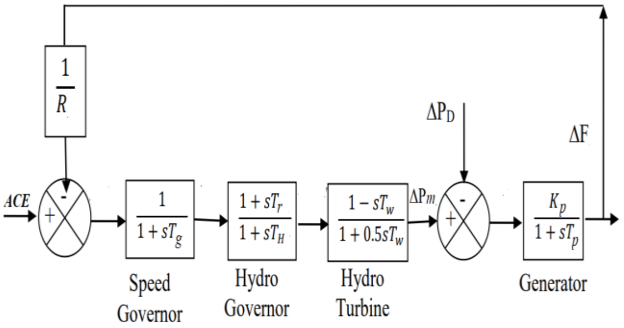


Fig 2. Block diagram of hydro power plant

D. Fuzzy logic based controller

It is based on a mathematical equation which is based on multiple inputs and an output source is very quick, robust. It can be most economical and easily manipulated. The control methodology is based on three stages namely, fuzzification, the inference rules engine and the defuzzification interface. Within the formal logic Toolbox, two forms of fuzzy inference will be implemented by Mamdani - type and Sugeno - type.

III. IMPLEMENTATION

A linearized model of three area non-reheat thermal generating units is considered for analysis of dynamic performance of the LFC. These areas are interconnected by using tie - line. The power system model consists of the speed governor, steam turbine as prime mover, rotating mass or load, appropriate for load frequency control. Three area power systems for Load frequency control are combined using tie-line function as shown in Fig 3.

The main difference between three areas is the settling time of the system in which case the later one is most slow process. It is certain that LFC has two control loops one act for primary control to topple small deviation that occurred within the area, while the secondary control loop gets activated only after primary controller has acted. This controller is examined in secondary control loop for deviation in frequency and tie-line power.

A. Need of Interconnection

Interconnected power system consists of one or more area is connected by tie – line is that the peak load of the power stations can be exchanged. In power station indicates a peak demand exceeding the rated capacity of the power station, then the excess load can be shared by other power stations interconnected.

B. Settling Time

It is defined as the minimum time required for a signal to become steady is called as settling time.

C. Overshoot

The maximum amplitude of the signal above the initial value, it occurs when the transition state is from lower to higher be called as overshoot.

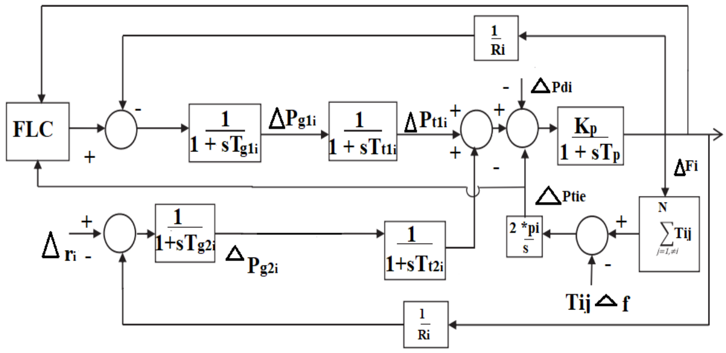


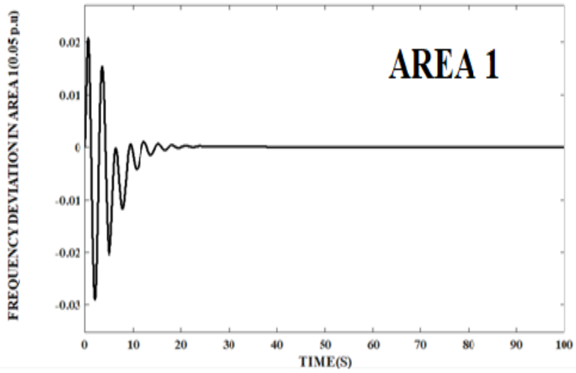
Fig 3. Proposed model of the i[th] area interconnected power system

D. Undershoot

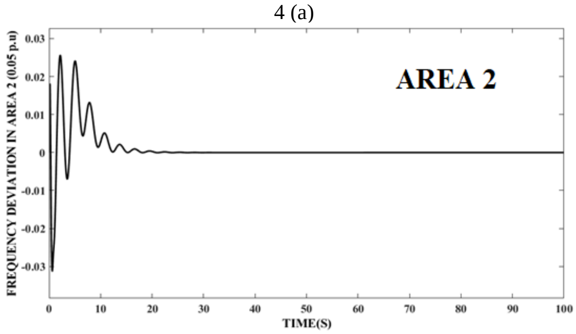
It occurs when the transition state is from higher to lower, and its value is lower than the final value.

IV. SIMULATION RESULTS

Simulation are done for three area interconnected power system connected with each other’s by tie transmission lines by using MATLAB / SIMULINK. This result illustrates the implementation of intelligent control technique controllers based on Fuzzy logic control. The proposed controllers are developed with aim to maintain the system stability and to minimize frequency deviation which are integrated power system consist of two thermal and hydro power generating units. Performance of these controllers is evaluated from better response obtained on MATLAB / SIMULINK with various step load disturbances.



4 (a)



4 (b)

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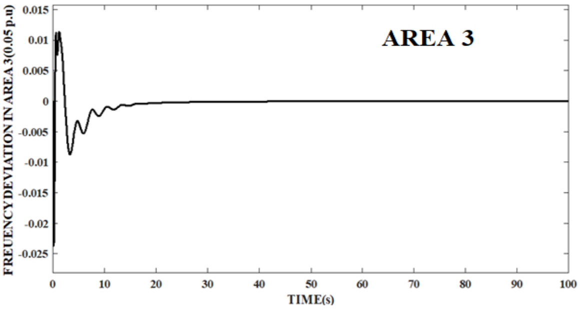

4 (c)

Fig 4. Frequency deviation in area 1, 2 and 3 during 0.05 step disturbance

Frequency deviations responses in area 1, 2, 3 during step disturbance 0.05 are shown in Fig 4(a, b, c).

Table I. Area parameters

PARAMETER	$AREA_1$	$AREA_2$	$AREA_3$
D_i	0.24	0.11	0.046
K_{ri}	0.3	0.3	0.3
M_i	167	89.5	23.25
R_i	0.04	0.04	0.04
T_{t1i}	0.4	0.4	0.1
T_{g1i}	0.1	0.1	0.4
T_{t2i}	1.0	1.0	1.0
T_{g2i}	0.1	0.1	0.1
T_{ri}	1.0	1.0	1.0
T_{ij}	T_{12}=8.4	T_{23}=2.3	T_{31}=1.5

This system is an actual three-area power system existing in the Arabian region where area 1 has 56 generating stations with total capacity of 4797 MW, area 2 has 88 generating stations with total capacity of 14,000 MW and area 3 has 28 generating stations with total capacity of 923 MW and the parameter are shown in Table I

Table II Results comparison for three area system during 0.05 step disturbance

AREA No.	STEP INPUT	SETTLING TIME
1	0.05	22 s
2	0.05	25 s
3	0.05	28 s

Tie – line power deviation response between area 1 - 2 and 2 – 3 are shown in Fig 5, 6.

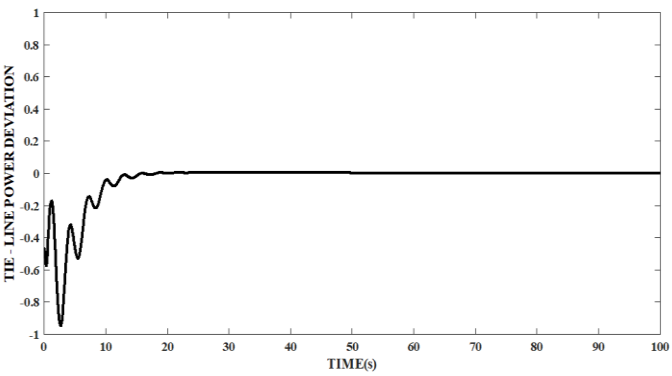

Fig 5.Tie - line power deviation between area 1 and 2

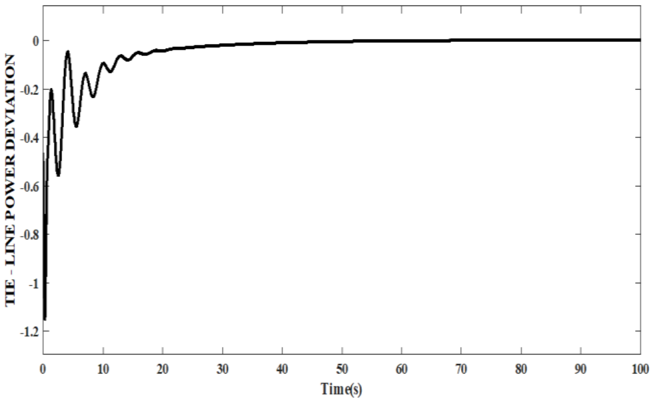

Fig 6.Tie - line power deviation between area 2 and 3

V. CONCLUSION

This paper presents a new load frequency controller for three area power systems. In case of three areas system, fuzzy logic based controller is designed to mitigate the frequency error when sudden increment of load occurs in the system. The situation is similar using step input function to replicate the sudden change in load that causes frequency deviations. The controller is used to monitor the power system, so it can maintain the changes in the load demand. Due to above phenomena there arises change in frequency due to which the stability of the system is maintained and tie - line power is reduced. It is also seen that fuzzy logic technique has faster convergence characteristics. The result shows the intelligent controller is having more improved deviation response.

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