H.D. Mathur

H.V. Manjunath

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Study of Dynamic Performance of Thermal Units with Asynchronous Tie-lines using Fuzzy Based Controller

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This paper investigates the load frequency control problem for a multi-area power system taking into consideration system parameter variations. This paper proposes an intelligent control scheme for load frequency control (LFC) of interconnected power systems. A fuzzy logic based integral controller is proposed for two area power system interconnected via parallel ac/dc transmission link. The simulation studies are carried out for a two area interconnected power system with reheat steam turbine for simplicity and without loss of generality. Suitable solution for load frequency control problem of two areas electrical power system is obtained by means of improving dynamic performance of power system under study. Robustness of controller is also checked by varying parameters. Simulation results indicate that the proposed control scheme work well when compared with others.

Keywords: Two area power system, load frequency control, fuzzy logic controller, gain scheduling

1. INTRODUCTION

The load frequency control is a technical requirement for the proper operation of an interconnected power system. For large scale electrical power systems that normally consist of interconnected control areas representing coherent groups of generators, load frequency control is very important in power system operation and control for supplying sufficient and reliable electric power with good quality. In cases of area load changes and abnormal conditions, such as outages of generation and varying system parameters, mismatches in frequency and scheduled tie-line power flows between areas can be caused. These mismatches are corrected by controlling the frequency, which is defined as the regulation of the power output of generators within a prescribed area [1-5]. The objective of the LFC is to satisfy the requirements such as zero steady state errors in tie-line exchanges and frequency deviations, optimal transient behaviors and in steady state, the power generation levels should satisfy the optimal dispatch conditions. Some intelligent controllers have been proposed to solve these problems but considering area interconnection with ac line. A little attention has been paid to use of HVDC transmission link as system interconnection. A favorable effect on system dynamic performance has been achieved considering such system interconnection. These studies are carried out considering the nominal system parameter values after linearization of the system about an operating condition. In practical cases, system parameters do not remain constant and continuously vary with changing operating conditions. Therefore, a serious concerned should be given to these parameter variation. The present paper is devoted to analyze the dynamic performance of two interconnected thermal units when equipped with HVDC transmission link parallel to AC tie line taking parameter uncertainties into account [6-7]. A fuzzy logic based intelligent controller is designed to facilitate the operation smooth and less oscillatory when system is subjected to a sudden load change [8-12]. The simulation results are presented and compared with other techniques.

Electrical and Electronics Engineering Group, Birla Institute of Technology and Science, Pilani (Rajasthan) –333031, India Email: mathurhd@gmail.com

2. TWO AREA POWER SYSTEM MODEL

The two area power system model identified in the present study has the following configuration;

(i) It is a two area interconnected power system consisting of identical power plants with reheat thermal turbines.

(ii) The two areas are interconnected via AC tie line in parallel with HVDC link.

The single line diagram of the model under consideration is presented in Figure 1 and its transfer function block diagram is described in Figure 2. The transmission links are considered as long transmission lines specifically of length greater than break even distance length of AC and HVDC transmission lines [6].

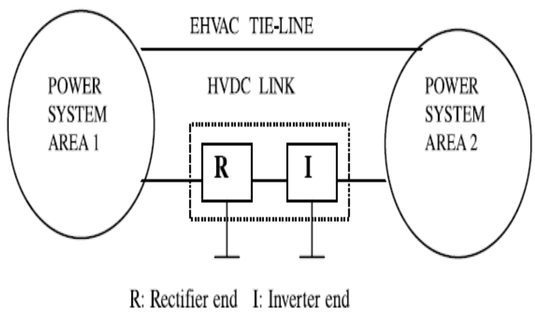

Figure 1: Two-area power system with parallel AC/HVDC links

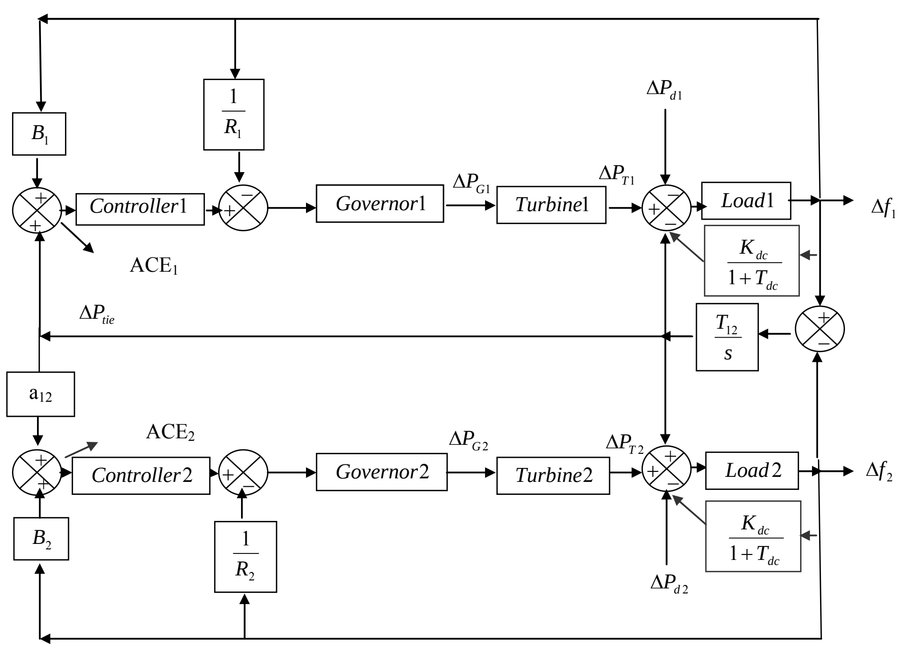

Figure 2: Transfer function model for system

Governor transfer function = $\dfrac{K_{Gi}}{1+sT_{Gi}}$,

Turbine transfer function = $\dfrac{1+sK_{ri}}{1+sT_{ri}}$ and

Load transfer function = $\dfrac{K_{Pi}}{1+sT_{Pi}}$, where i=1 and 2 for area 1 and 2 respectively while R is regulation constant (Hz/per unit), T_G is speed governor time constant (s), T_T is reheat steam turbine time constant (s) and Tp is power system time constant (s). HVDC link is also represented in the form of a transfer function as given in the Figure 2 in which K_{dc} and T_{dc} are gain and time constant (s) of the HVDC link.

3. FUZZY LOGIC CONTROLLER

Fuzzy set theory and fuzzy logic establish the rules of a nonlinear mapping [14]. The use of fuzzy sets provides a basis for a systematic ways for the application of uncertain and indefinite models. Fuzzy control is based on a logical system called fuzzy logic which is much closer in spirit to human thinking and natural language than classical logical systems. Nowadays fuzzy logic is used in almost all sectors of industry and science. One of them is load frequency control. The main goal of LFC in interconnected power systems is to protect the balance between production and consumption. Because of the complexity and multi-variable conditions of the power system, conventional control methods may not give satisfactory solutions. On the other hand, their robustness and reliability make fuzzy controllers useful in solving a wide range of control problems [15, 16]. The fuzzy controller for the single input and single output type of systems is shown in Figure. 3.

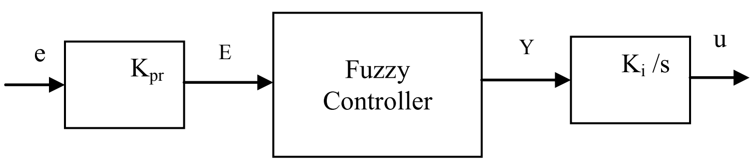

Figure 3: The SISO type fuzzy controller

Table 1 Fuzzy logic rules for the Integral gain

ACE \ Δ ACE	LN	MN	SN	Z	SP	MP	LP
LN	LP	LP	LP	MP	MP	SP	Z
MN	LP	MP	MP	MP	SP	ZE	SN
SN	LP	MP	SP	SP	Z	SN	MN
Z	MP	MP	SP	Z	SN	MN	MN
SP	MP	SP	Z	SN	SN	MN	LN
MP	SP	Z	SN	MN	MN	MN	LN
LP	Z	SN	MN	MN	LN	LN	LN

LN: large negative, MN: medium negative, SN: small negative, Z: zero, SP: small positive, MP: medium positive and LP: large positive

In the Fig. 3 shown above, K_{pr} and K_i are the proportional and integral gains respectively. In this study derivative of E together with *E* is fed to fuzzy controller. The fuzzy controller block is formed by fuzzification of E and dE/dt , the inference mechanism and defuzzification. Therefore, Y is a crisp value and u is a control signal for the system. Mamdani fuzzy theory is applied in determining the gain of controller. Table 1 is presenting the rules for fuzzy logic controller under study

4. SIMULATION RESULTS

In this paper, a fuzzy logic controller has been applied to a two area power system with reheat turbine. MATLAB 7 is used for simulation purpose. The same values of system parameters [6, 7], given in Table 2, are used for all controllers for a comparative study. There are 7 triangular membership functions considered for inputs (E and $\frac{dE}{dt}$) and one output (Ki). In all 49 rules are designed to get the response.

Table 2: System parameters

Rating (MW)	2000
T_{G1} and T_{G2} (sec.)	0.08
T_{T1} and T_{T2} (sec.)	0.3
B_1 and B_2 (pu MW/Hz)	0.425
R_1 and R_2 (Hz/ pu MW)	2.4
K_{p1} and K_{p2}	120
T_{p1} and T_{p2} (sec.)	20
K_{r1} and K_{r2}	0.5
T_{r1} and T_{r2} (sec.)	10

The response plots for variables like frequency deviations in area 1 and area 2 and ac tie line power deviations for both power system models i.e. with HVDC link and without HVDC link, in the wake of load disturbance in area 1 of 1%, are obtained with the implementation of fuzzy logic controller to analyze the system dynamic performance. Figure 4 (a) shows the responses when same parameters are taken while Figure 4 (b) and Figure 4 (c) show the variations when main parameters (i.e. B, T_P and T_{12}) of power system model are varied +30 % and -30 % respectively. Dynamic performance parameters i.e. settling time and peak overshoot of the responses of area 1 are listed in tabular form in Table 3 since area 1 is disturbed.

Table 3: Comparative statement of dynamic parameters in both cases

Value of Parameters	With HVDC Link		Without HVDC Link	
	Settling Time (s)	Peakovershoot (Hz)	Settling Time(s)	Peakovershoot (Hz)
Nominal	4.33	-0.0115	18.15	-0.025
+30 % of Nominal	3.266	-0.0100	18.6	-0.020
-30 % of Nominal	10.97	-0.0137	14.3	-0.0328

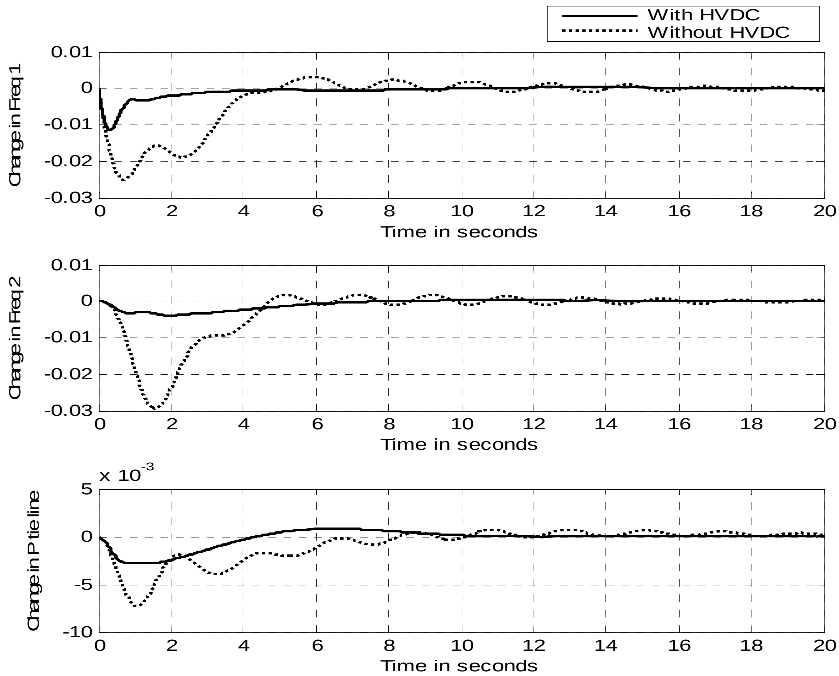

Figure 4 (a): Responses with standard system parameters

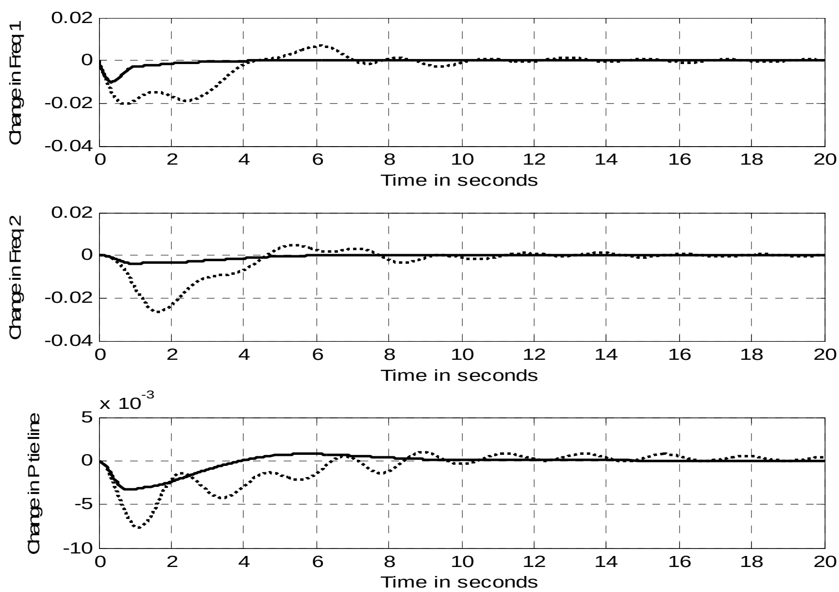

Figure 4 (b): Responses with + 30 % variations in B, T_P and T_{12}

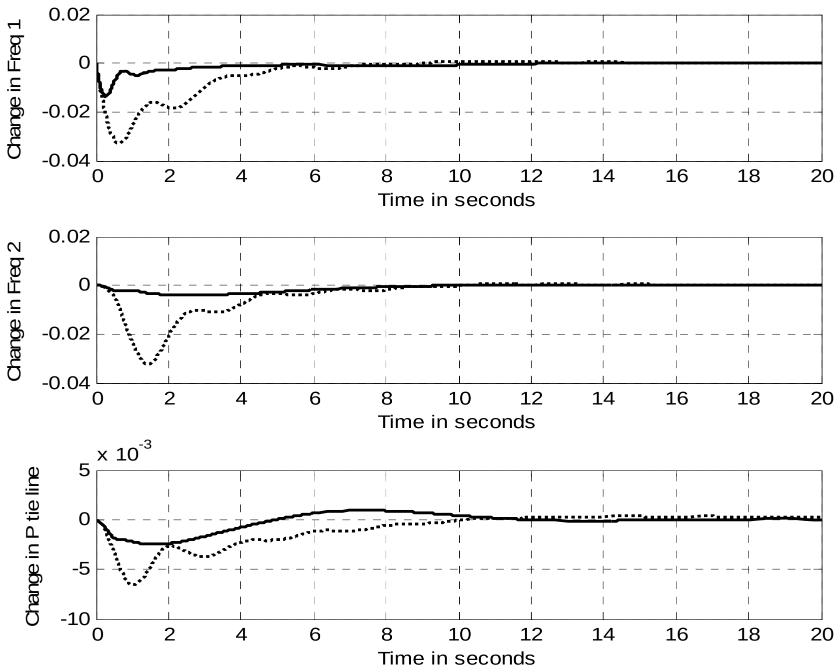

Figure 4 (c): Responses with – 30 % variations in B, T_P and T_{12}

Simulation results show that when HVDC link is incorporated in two area interconnected systems, which are equipped with reheat steam turbines, dynamic performance improves to a large extent. Implementation of HVDC link parallel to present AC line may definitely be a costly affair but enhancement in settling time and peakoverhoot can justify it. Load frequency control problem is one of major problem in present day power system and electrical utilities are also bound to supply quality and reliable power to its consumers in cut throat competition. Therefore, in order to have quality and reliable power HVDC link connection has helped in drastic reduction of sustained oscillations.

5. CONCLUSIONS

In this paper, a new power system model is proposed to improve the dynamic performance of interconnected system. New model consisting of a fuzzy logic controller along with a HVDC link connected parallel to ac tie-line. The system dynamic performance in the wake of load disturbance in one area of interconnected power system has been investigated comprehensively. Power system model with identical thermal units with reheat turbines are considered for the study. A new intelligent control strategy is designed and its feasibility is studied by varying system parameters. Simulation results presented justify the incorporation of HVDC link to supply consumers reliable and quality power.

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