

AGC of a Two-Area Interconnected Non-Reheat Power System with a Parallel HVDC Link using PI Controller and Fuzzy Logic Controller.

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Abstract: The design of Automatic Generation Control (AGC) system plays a vital role in automation of Power System. This paper investigates the effects of proportional integral controller and fuzzy logic controller in a two area interconnected non-reheat power system having HVDC link connected in parallel with HVAC. The dynamic performance of system has been compared with Proportional Integral controller and Fuzzy logic controller and observed that the performance is superior in terms of overshoot and settling time when Fuzzy Controller is used.

Keywords: Automatic Generation Control (AGC), Proportional Integral (PI) Controller, MATLAB/SIMULINK, HVDC link, Fuzzy Logic Controller.

1. INTRODUCTION

The automatic generation control (AGC) is a technical requirement for the proper operation of an interconnected power system. Automatic generation control is very important in power system operation and control for supplying sufficient and reliable electric power with good quality, particularly for large scale electrical power systems that normally consist of interconnected control areas representing coherent groups of generators. 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. Automatic generation control is 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 schedule system frequency and establish the interchange with other areas within predetermined limits [1].

A little attention has been paid to use of HVDC transmission link as system interconnection. However, there has been a tremendous growth of the HVDC transmission system due to economic, environmental and performance advantages over the other alternatives. Hence it has been applied widely in operating a dc link in parallel with an HVAC link interconnecting control areas to get an improved system dynamic performance with greater stability margins under small disturbances in the system [2]-[4]. In practical cases, system parameters do not remain constant and continuously vary with changing operating conditions. To solve this problem various recent trend intelligent controllers are discussed in [5,6]. A number of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic performance. Among the various types of load frequency controllers, the most widely employed is the conventional proportional integral (PI) controller [7,8]. The conventional control method does not give required solutions due to complex and multivariable power systems. Therefore next step is taken to improve the reliability and robustness of the system using Fuzzy Controllers. Fuzzy Controllers are advantageous in solving wide range of control problems including AGC of interconnected power system. Fuzzy logic based controller can be implemented to analyze

the load frequency control of two area interconnected power system with HVAC and HVDC parallel link taking parameter uncertainties into account. The power system is modeled and simulated using MATLAB simulink environment. Then the frequency deviation has been studied and presented with and without integral controller, fuzzy controller.

I. PROBLEM FORMULATION

Investigations have been carried out on a two area power system. A step load perturbation of 1% of nominal loading has been considered in area-1. For the load frequency control, the conventional and intelligent controllers are implemented.

A. Two Area Power System

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

- a) It is a two area interconnected power system consisting of identical single stage non-reheat thermal turbines.
- b) The two areas are interconnected via HVAC tie line in parallel with HVDC link. The step load perturbation of 1% of the nominal loading has been considered in either of the area for system analysis.

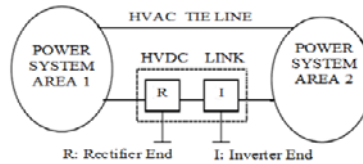


Fig 1: Single line diagram of two area power system with parallel HVAC/HVDC links

B. Proportional plus Integral Controller

The steady load frequency characteristic for a given speed changer setting has considerable droop, e.g. for the system being used, the steady state droop in frequency will be 2.9 Hz from no load to full load (1 pu load). System frequency specifications are rather stringent and, therefore, so much change in frequency cannot be tolerated. In fact, it is expected that the steady change in frequency will be zero. While steady state frequency can be brought back to the scheduled value by adjusting speed changer setting, the system could undergo intolerable dynamic frequency changes with changes in load. It leads to the natural suggestion that the speed changer setting be adjusted automatically by monitoring the frequency changes. For this purpose, a signal from Δf is fed through an integrator. The system now modifies to a proportional plus integral controller, which, is well known from control theory, gives zero steady state error, i.e. Δf steady state = 0.

The signal $\Delta P_c(s)$ generated by the integral control must be of opposite sign to $\Delta F(s)$ which accounts for negative sign in the block for integral controller.

Now

$$\Delta F(s) = - \frac{K_{ps}}{(1 + T_{ps}S) + (\frac{1}{R} + \frac{K_i}{s})} \times \frac{\Delta P_D}{s} \times \frac{K_{ps}}{(1 + T_{sg}S)(1 + T_1S)}$$

$$\frac{\Delta P_D}{s} \Delta f_{steady\ state} = s_{x \rightarrow 0} \Delta F(s) = 0$$



C. HVDC Link

High Voltage Direct Current (HVDC) system plays vital role in today's power system around the world and will continue to contribute more with the advent of Smart Super Grid in the future. Over the past few decades expanding power grids has proven to be both economically and environmentally desirable. The utilization of time zone, seasonal diversity that may exists between adjacent power systems can postpone or eliminate the necessity of building redundant generation units. Benefits of using HVDC system or Hybrid AC/DC system has been discussed from different projects in order to create secure, stable and reliable grid for the deregulated electricity market.

HVDC is a proven technology employed for power transmission. The power is taken from one point in an AC network and converted to DC in a converter station (rectifier) and transmitted over a line and converted back to AC again in another converter station (inverter) before it is injected into the receiving AC network. HVDC interconnection could contribute better to both technical and economic advantages of interconnection system. The most common reasons behind the choice of HVDC are:

- 1) Lower line costs – beyond a certain distance (the break-even distance) the DC line will pay for the investment cost for the DC stations.
- 2) Lower losses - with HVDC, no reactive power is transmitted. The line losses are lower than AC. The losses in the converter terminals are approximately 1.0 – 1.5 per cent of the transmitted power, which is low, compared with the line losses.
- 3) Stable operation at low power flow is also among the other advantages taken into consideration.

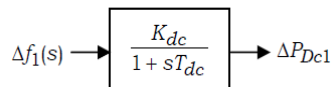


Fig 2: Transfer function of HVDC

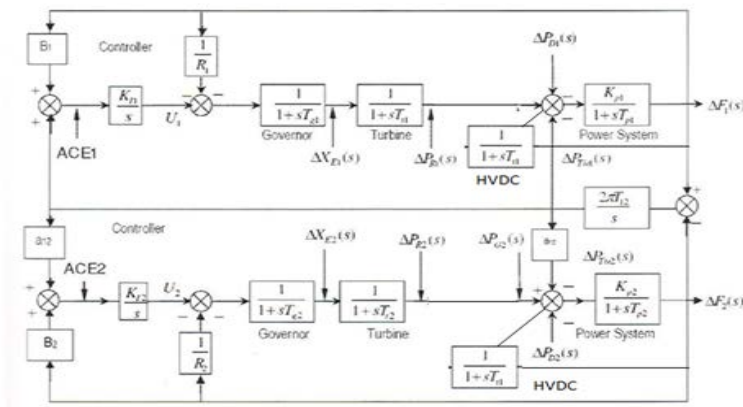


Fig 3: Block diagram of two-area load frequency control in regulated system with HVDC link and PI controller.

D. Fuzzy Logic Controller



The Fuzzy logic controller uses the fuzzy logics to make the decisions and to control the output of the controller. The main components in fuzzy logic based MPPT controller are fuzzification, rule-base, inference and defuzzification as shown in figure 3.

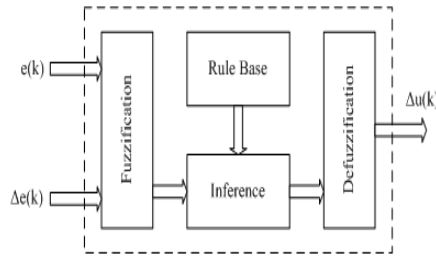


Fig 4: Fuzzy Logic basic block diagram

There are two inputs to the controller – error ACE and change in error ΔACE. The Fuzzification block converts the crisp inputs to fuzzy inputs. The rules are formed in rule base and are applied in inference block. The defuzzification converts the fuzzy output to the crisp output. The fuzzy inference is carried out by using Mamdani’s method, and the defuzzification uses the centre of gravity to compute the output of this FLC which is the change in duty cycle.

II. METHODOLOGY

The fuzzy logic controller used in the system has two inputs. The error is the change in area control error (ACE) The equation for error and change in error is given by

$$ACE = b\Delta f_1 + \Delta P_{tie}$$

A. Rule Base

TABLE 1: RULE BASE

ΔACE	NL	N	Z	P	PL
ACE					
NL	PL	PL	PL	-	-
N	PL	P	P	-	-
NZ	PL	P	P	-	-
Z	-	-	-	N	NL

PZ	-	-	N	N	NL
P	-	-	N	N	NL
PL	-	-	NL	NL	NL

B. Membership Function

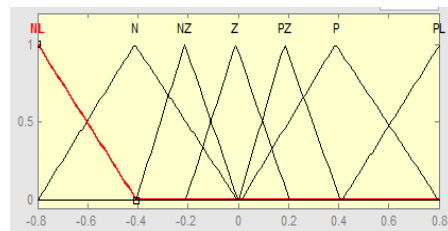


Fig 5 : Membership function of ACE



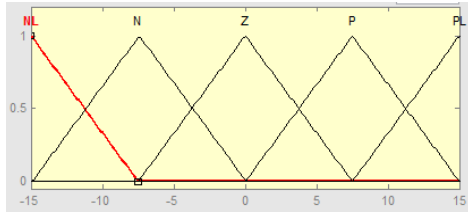


Fig 6 : Membership function of ΔACE

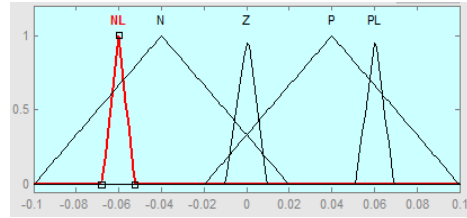


Fig 7: Membership function of output

2. Simulation Results

In this paper, a fuzzy logic controller has been designed and applied to analyze the effect of HVDC link on the AGC of two area interconnected power system. The implementation worked with Matlab-Simulink software. The response plots for variables like frequency deviations in area 1 and area 2 and tie line power deviations for power system model, in the wake of load disturbance of 1% in area 1 are obtained with the implementation of PI controller and fuzzy logic controller to analyze the system dynamic performance.

A. Comparison of system performance using PI controller, with HVDC link & without HVDC link

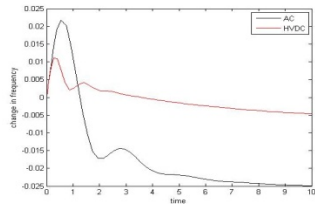


Figure 8: Change in frequency in area 1

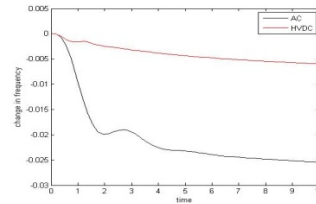


Figure 9: Change in frequency in area 2

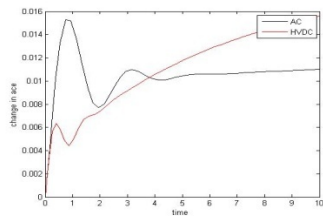


Figure 10: Change in area control error of area 1

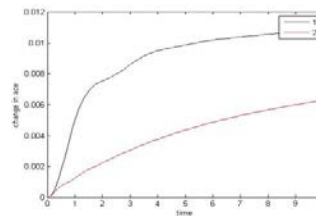


Figure 11: Change in area control error of area 2

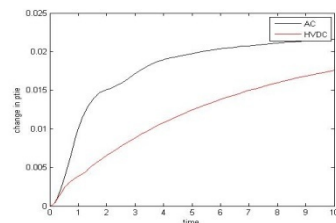


Figure 12: Change in tie-line power

From Figure 8 to Figure 12 shows the comparison of change in Area Control Error, frequency of area 1 & 2 and change in tie-line power. Comparison graphs shows that the settling time, overshoot time is reduced, hence stability of the system get improved while using HVDC link in parallel to AC link.

B. Comparison of System Performance with Fuzzy Logic Controller & without Fuzzy Logic Controller.

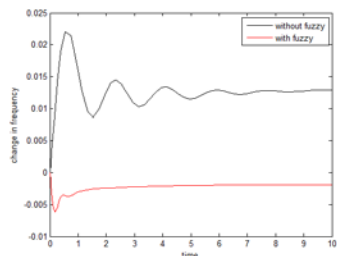


Figure 13: change in frequency of area 1

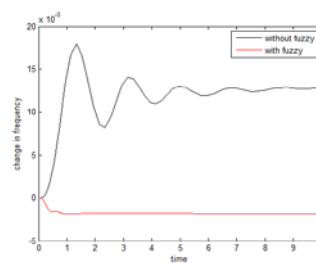


Figure 14: change in frequency of area 2

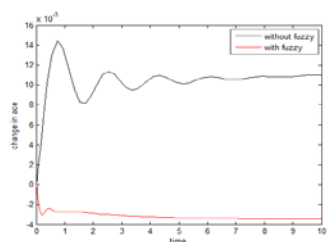


Figure 15: change in Area Control Error of area 1

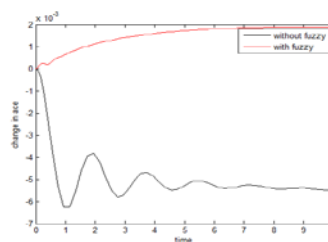


Figure 16: change in frequency of area 2

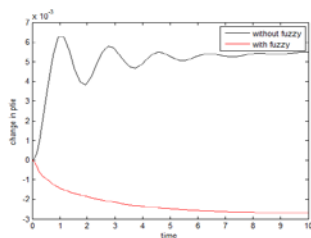


Figure 17: change in tie line power



From Figure 13 to Figure 17 shows the comparison of change in Area Control Error, frequency of Area 1 & 2 and change in tie-line power. Comparison graphs shows that settling time and overshoot time gets improved when Fuzzy Logic Controller is used.

3. Conclusion

In this paper, a power system model is proposed to improve the dynamic performance of two area interconnected power system by the use of HVDC link in parallel with existing HVAC link. A fuzzy logic control strategy is designed and its feasibility is studied by varying system parameters. It has been observed that responses of the system with parallel HVDC link are better in terms of dynamic parameters such as peak overshoot and settling time. HVDC gives many benefits for transmission interconnections. These benefits may be economical, environmental or technical. The ability of HVDC systems to control power flow and prevent propagation of severe disturbances, thus limiting blackout extension and ability to maintain independence of interconnected networks is of prime importance when the two systems have different regulatory procedures and also for technical reasons, if the load frequency control regimes are not compatible. Simulation results presented justify the incorporation of HVDC transmission link to supply consumers reliable and quality power. It has been observed that responses of the system with fuzzy logic controller are better in terms of dynamic parameters such as peak overshoot and settling time.

4. Appendix

Nominal parameters of the Two-area system investigated:

$P_{r1}=2000$ MW; $P_{r2}=4000$ MW; $P_{r3}=8000$ MW; $P_{r4}=10000$ MW;
 $R_1=R_2=R_3=R_4=2.4$ HZ/p.u.MW;
 $B_1=B_2=B_3=B_4=0.425$ HZ/p.u.MW;
 $T_{sg1}=T_{sg2}=T_{sg3}=T_{sg4}=0.08$ seconds;
 $T_{t1}=T_{t2}=T_{t3}=T_{t4}=0.3$ seconds;
 $T_{ps1}=T_{ps2}=T_{ps3}=T_{ps4}=20$ seconds;
 $T_{12}=T_{13}=T_{14}=T_{23}=T_{24}=T_{34}=0.086$ p.u.MW/Radian;
 $a_{ij}=-P_{ri}/P_{rj}$;
 $T_{r1}=T_{r2}=T_{r3}=T_{r4}=10$ seconds;
 $K_{r1}=K_{r2}=K_{r3}=K_{r4}=0.5$;
 $P_{tie, max}=200$ MW;
 $F=50$ HZ; $K_{dc1}=K_{dc2}=K_{dc3}=K_{dc4}=1.0$;
 $T_{dc1}=T_{dc2}=T_{dc3}=T_{dc4}=0.2$ seconds;
 $\Delta P_{di}=0.01$ p.u.MW

References

- [1] O.I. Elgerd, "Electric Energy Systems Theory: an introduction," Tata Mc-Graw Hill Publishing Company Limited, New Delhi, India, 2008.
- [2] Ibraheem and P. Kumar, "Study of dynamic performance of power systems with asynchronous tie-lines considering parameter uncertainties," Journal of Institution of Engineers (I), vol. 85, pp. 35-42, 2004.
- [3] Ibraheem and P. Kumar, "Dynamic performance enhancement of hydro-power systems with asynchronous tielines," Journal of Institution of Engineers (I), vol. 85, pp. 23-34, 2004.



- [4] Ngamroo, "A Stabilization of frequency oscillation in a parallel ac-dc interconnected power system via an HVDC Link," Science Asia, vol. 28, pp. 173-180, 2002.
- [5] H.D. Mathur and H.V. Manjunath, "Study of dynamic performance of thermal units with asynchronous tie-lines using fuzzy based controller," Journal of Electrical System, vol. 3, no. 3, pp. 124-130, 2007.
- [6] D.M.V. Kumar, "Intelligent controllers for automatic generation control," in Proc. of IEEE region 10 International Conference on Global connectivity in Energy, Computer, Communication and Control, Dec. 17-19, New Delhi, India, vol. 2, pp. 557-574.
- [7] H.D. Mathur and S. Ghosh, "A Comprehensive analysis of intelligent controllers for load frequency control," in Proc. of IEEE Power India 2006 Conferenc, April 10-12, Delhi, 2006.
- [8] M. L. Kothari, J. Nanda, D. P. Kothari, and D. Das, "Discrete-mode automatic generation control of a two-area reheat thermal system with new area control error", IEEE Trans. Power Syst., Vol. 4, No. 2, pp. 730-738, May 1989.
- [9] DP Kothari, IJ Nagrath," Modern power system analysis", third edition.
- [10] Yogendra Arya, Naredra Kumar, Hitesh Dutt Mathur,2012." Automatic Generation Control in Multi Area Interconnected Power System by using HVDC Links", International Journal of Power Electronics and Drive System (IJPEDS) Vol.2, No.1, March 2012, pp. 67~75 ISSN: 2088-8694
- [11] C.Srinivasa Ra1, S.Siva Nagaraju, and P.Sangameswara Raju,2009." Improvement of Dynamic Performance of AGC under Open Market Scenario Employing TCPS and A.C-D.C Parallel Tie Line", International Journal of Recent Trends in Engineering, Vol 1, No. 3, May 2009

