MODELING AND SIMULATION OF AGC SYSTEMS FOR EFFICIENT LOAD FREQUENCY CONTROL IN RESTRUCTURED HYDRO-THERMAL POWER PLANTS

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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).*

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).

LITERATURE REVIEW

Deepak Kumar (2021) This paper deals with a new control strategy of quenching transients of a load frequency problem. The load frequency problem is represented by a new state space model for a single area Electric power system. Global analysis of the power system markets shows that load frequency control (LFC) is one of the most profitable ancillary services of these systems. This service is related to the short-term balance of energy and frequency of the power systems and acquires a principal role to enable power exchanges and to provide better conditions for electricity trading. The state variables selected in this model are frequency, first and second derivatives of frequencies. The steady state operating points before and after the load disturbance are named as initial and final states of the system. Now the LFC problem is restructured as a state transition problem (initial to final states) using a suitable control parameter.

Nizamuddin Hakimuddin [2020] explores the potential of implementing automatic (AGC) two-area, multiple focus on its practicality. There has been a noticeable increase in the number of wind power plants (WPPs) in recent years. WPPs have the potential to generate energy that is environmentally friendly and can be sustained over time. However, it is worth noting that WPP activities have been associated with certain stability concerns in the system, primarily due to the relatively lower levels of inertia. While AGC has the potential to address generation and demand mismatch, it is important to consider that WPPs may introduce some challenges due inherent volatility of wind energy. This can be attributed to the inherent variability of wind power. To effectively analyse the dynamic performance system, we have developed an optimal controller utilising the principles of full state feedback control theory.

KostiantynProtchenko [2019] conducted a study in a humid continental climate to explore the most effective positioning of thermal insulation in a building envelope wall that is supported by a layer of cement stabilised rammed earth (CSRE). The main objective of this study was to identify a suitable location for the installation of thermal insulation. This article not only introduces the concept of CSRE but also provides valuable guidance on determining the optimal wall thickness for its application. Furthermore, it is worth noting that the most recent standard values of the heat transfer coefficient for exterior walls are presented alongside the research findings of the thermal conductivity coefficient of CSRE for several countries that experience a humid continental climate. This data can be valuable in determining the appropriate thickness of a CSRE layer to ensure sufficient thermal insulation for walls within a building's envelope.

Pankaj Mukhija [2016] conducts a study practicality optimal context of automatic generation control (AGC) for electric power producing systems. The term automatic generator control (AGC) refers to the method employed for managing the transfer of energy between power plants. The consideration of minimising the performance index is often utilised as a criterion in the development of an optimal controller. In order to conduct the study, a variety of models from the current literature are simulated, with a brief load perturbation being introduced.

HYBRID MODELS

The integration of the renewable energy resources into the power system creates new issues because most of them are whether dependent. Power systems need advanced control methods for its daily management. In the control area, the new tendency is the combination of the artificial intelligence algorithms particle swarm optimisation algorithm (PSO), fuzzy logic (FL), genetic algorithm (GA), etc. with the conventional controller to solve the frequency or active power flow control issue in power system. Some models based on FL approach are available in the literature [18].

LFC based particle swarm optimisation algorithm

PSO algorithm is one of the best algorithm in the artificial intelligence class. Multi-stage fuzzy LFC using PSO was proposed [19]. For achieving the desired level of robust performance, exact tuning of membership functions was very important. Intelligent frequency control in an AC microgrid on- line PSO-based tuning approach was presented in Bevrani [20]. The performance of the proposed model was compared with the pure fuzzy PI and the Ziegler–Nichols PI control design methods. A novel hybrid PSO–PS optimised fuzzy PI controller for AGC in multi area interconnected power systems have proposed [21]. Additionally, the proposed approach was further extended to multi-source multi area hydro thermal power system with/without HVDC link. Using a PSO and fuzzy rules the authors presented a multi-area LFC. Heuris- tic procedures involving Particle Swarm Intelligence and Fuzzy based inferences have been employed to effectively obtain the optimised gains of PID controller

LFC based genetic algorithm

Research on LFC based on GA can be found in the available literature. The authors have pro- posed an AGC of multi-area power system using multi-objective non-dominated sorting genetic algorithm-II. The proposed approach was first applied to a linear two-area power system model and then extended to a non-linear system model by considering the effect of governor dead band non-linearity[23]. A modified GA based load frequency controller for interconnected power systems was proposed. Floating point representation has been used, since it was more consistent, more precise and leads to faster convergence.[24] have proposed two robust decentralised control design methodologies for LFC.

LFC other models based on artificial intelligence algorithm

This section gives the controllers models based on algorithm using artificial intelligence strategies. The research in presents the design of optimal AGC regulators using an output feedback control strategy for a multi-area interconnected power system. [26] has proposed a comparative performance analysis of TLBO for automatic LFC of multi-source power systems. It was found that the dynamic performance of the proposed controller was better than that of recently published DE optimised controller and optimal output feedback controller and also the proposed system was more robust and stable to wide changes in system loading, parameters, size and locations of step load perturbation and different cost functions. [27] have proposed an observer based robust integral sliding mode LFC for wind power systems

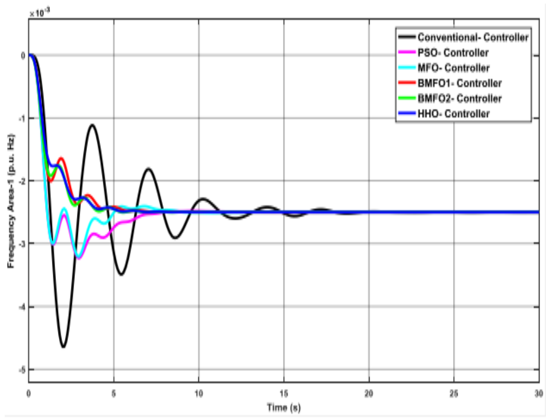
METHODOLOGY

It is possible to manipulate the active power regulation of the Load Frequency regulation (LFC) system via the complex adjustment of many controllers and sources included within the system. In the complex world of power system networks, there are three main categories that may be made about the possible interconnections of controllers. These classifications are discussed below. The central controller, the solitary agent, and the decentralised controller are the essential modes of control that may be found within this complex domain. These categories describe the fundamental modes of control. In the case that there is a central controller, there is only one control unit that is used and it is coupled with all areas within the power system network. This is done for the goal of controlling parameters of those regions and maintaining the equilibrium between generation and demand. In addition, the control action is only carried out on the specific distributed generation system when using the single agent technique.

RESULTS

Bilateral based Transaction

As can be seen in Figures 1, there is a wide range of dynamic responses to the ingress common.



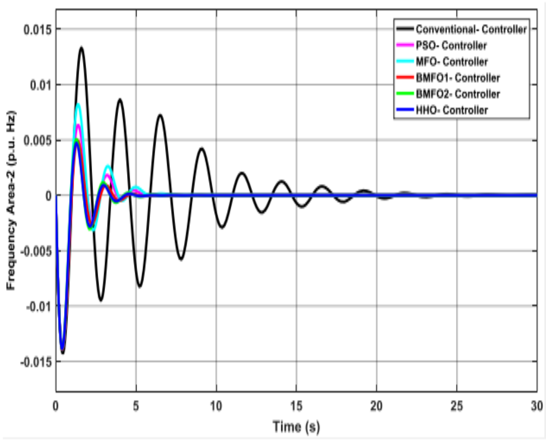
Graph 1: Bilateral Contract Dynamic Response of Area-1 Frequency Using Multiple Controllers

Table: 1 Bilateral Contract Frequency Analysis for Area-1 Using Different Controller Graph

Controller	DelayTime	RiseTime	PeakOvershoo	Settling Time

			t Time	
Conventional	-2.414	-4.205	-4.668	23.39
PSO	-1.508	-2.715	-3.015	21.17
MFO	-1.503	-2.706	-3.005	21.02
BMFO1	-1.003	-1.807	-2.007	21.44
BMFO2	-0.978	-1.768	-1.956	21.43
HHO	-0.835	-1.499	-1.664	20.86

If we look at Fig. 2 and Table 2, we can see how the conventional, PSO, MFO, BMFO1, BMFO2, and HHO controllers for Area1 vary from one another in terms of how they respond to changes in amount time in seconds results obtained with the HHO controller are noticeably superior to those obtained with the controller that was used before (delay time = -0.835 seconds, settling time = 20.86 seconds).



Graph. 2: Bilateral Contract Dynamic Response of Area-2 Frequency with Different Controllers

Table-2: Using a Bilateral Contract, we analyse the frequency graph in Area-2 with different controllers.

Controller	Delay Time	Rise Time	Peak Overshoot Time	Settling Time
Conventional	0.0066	0.0118	0.0131	23.39
PSO	0.0031	0.0047	0.0052	21.17

MFO	0.0045	0.0074	0.0081	21.01
BMFO1	0.0027	0.0047	0.0052	21.43
BMFO2	0.0027	0.0049	0.0054	21.43
HHO	0.0024	0.0042	0.0043	20.86

The Area-2 frequency with respect to time in seconds is analysed and compared in Fig. 5.10 and Table 5.28. The controllers that are being compared include conventional, PSO, MFO, BMFO1, BMFO2, and HHO. This comparison is being done under the terms of a bilateral contract analysis of comparison findings reveals an improvement performance HHO controller, which now has a delay time seconds and a settling time of 20.86 seconds.

CONCLUSION

The present paper review the comprehensive literature concerning the load frequency controller models. There cent issues and challenges faced by these controllers as well as by the power system in order to maintain the frequency of the system to nominal values and to maintain the voltage and active power profile within predetermined limits are also addressed in this paper. The frequency control is a major issue in the power system operation and control and lot of advanced control strategies have been developed over the last decades in order to improve the frequency control of the power system. However, there is a growing trend to develop microgrids which may be operated in grid connected or isolated mode. The microgrids essentially have unpredictable renewable sources of energy besides storage.

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