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An Analysis of Various Control Schemes for Multiarea LFC

Reena Chauhan[1], Dr. Charu[2]
[1]Dev Bhoomi Uttarakhand University, Dehradun
[2]Quantum University, Roorkee

Abstract- Automatic generation control, often known as AGC, is necessary in order to ensure that a power system network operates in a consistent manner. The LFC is primarily responsible for controlling the output of the generator in response to changes in the tie-line power and the frequency of the network. Some examples of this include reestablishing the frequency that was intended and exchanging power with other sites within the parameters that were previously established. In this work, the performance of several load frequency control techniques is compared using secondary controllers. These controllers include proportional plus integral plus derivative (PID), integral double derivative (IDD), model predictive control (MPC), and fuzzy cascaded PID. Through the use of a generation rate constraint (GRC), the study is carried out for thermal reheat systems that consist of three areas as well as five areas. A well-known optimization technique known as Big Bang Big Crunch (BBBC) is used in order to ascertain the optimal gains for PID controllers. In order to evaluate the responsiveness of the controllers, a number of different load perturbations in a number of different places have been taken into account. On the basis of settling time, overshoot, and undershoot, it has been able to make comparisons between the results. In every scenario, with the exception of a few peaky oscillations in responses, it is seen that fuzzy cascaded PID works better than other controllers, notably in terms of settling time. This is the case regardless of the conditions. Furthermore, in contrast to conventional controllers, the fuzzy cascaded PID controller has a greater degree of flexibility and durability.

Keywords: Automatic Control Error (ACE); Fuzzy Logic Control (FLC); Integral Double Derivative (IDD); Load Frequency Control (LFC); Model Predictive Control (MPC)

I. INTRODUCTION

In power systems, frequency control is the responsibility of load frequency control, or LFC, after any imbalance between generation and load need. Maintaining the planned frequency and tie-line power under typical circumstances is the aim of the LFC. Primary control and secondary control are the two stages or loops in power systems where the LFC is used [1]. Automatic generation control (AGC) is the mechanism in an electrical system that manages secondary frequency regulation. It maintains an area's generation-load within a certain range and handles any imbalances in frequency and power exchange when a load shift occurs. [1-2]. The electricity system is separated into control regions in order to improve control since it is a large network. Tie-lines are used to link two control areas so they may share power and assist one another in an emergency. [3–4].

In an interconnected power system, a change in load in any one of the areas results in variations in both the area's frequency and the tie line's power. Therefore, a proper control system for a networked power system is often included in an LFC design. A review of the literature reveals that control structure and fitness function have an impact on power system performance. As such, suggestions for and applications of novel high speed optimization methods to practical problems are constantly appreciated. In LFC, the controller is crucial to preserving balance. As a result, a variety of techniques—classical, adaptive, optimum, nonlinear, contemporary, etc.—have been used in literature.

Furthermore, LFC controllers based on different soft computing techniques, such ant colony (ACO), GA, PSO, HS, ANN, fuzzy, etc., are also implemented using control systems [5–9]. A traditional system with a combination of hydro and thermal components has been researched in the past. Researchers choose I, PI, and PID [10] because of their advantages, which include quick implementation, high performance, and a straightforward design. Numerous systems, including electricity systems, have successfully shown the efficacy of various control strategies. Nonetheless, research has shown that when there are a lot of factors that need to be adjusted, the usual method is most certainly not the best option.

Still, one of the main concerns is the stability of the power supply. This expands the function and accountability of the control strategies used in the power system [11–13]. Using traditional controllers has a number of disadvantages, including their slow operation, their inability to account for the inherent nonlinearities of various power system components, and the challenge of adjusting the integrator setting's gain in response to variations in the operating point. An advanced control system has several benefits over a conventional integrated controller. They move much more quickly. The altered environment necessitates various control systems as adaptive neuro fuzzy inference system (ANFIS), NARMAL-2 controller, etc [14-15]. Mamdani developed the first fuzzy logic control method for a steam engine, while Zadeh introduced the notion of fuzzy sets [16–17]. The performance of a fuzzy logic controller depends on the expertise and experience of a human operator. Model predictive control, or MPC, generates the best control by projecting the system's future output. It has also been used to regulate the frequency of power systems that include dc grid, SMES, and wind turbines [18–21]. Because every control strategy has advantages and disadvantages, the authors of this research compared the effectiveness of PID, fuzzy PID, IDD, and MPC on reheat thermal power systems with three and five areas.

This paper's primary contributions are as follows: (1) The case study includes three and five area thermal power systems. (2) Control techniques such as PID, IDD, Fuzzy PID, and MPC have been developed for LFC. (3) Control strategies are designed using a simulation model of the three-area and five-area power system that is given. (4) Under various disturbance situations, the efficacy and performance of all control techniques have been investigated.

There are five parts in this study. The modeling of three- and five-area power systems is introduced in Section 2. Section 3 provides an explanation of each control strategy. Sections 4 and 5 present and compare the outcomes achieved with each control technique. Section 6 finally brings the research analysis to a close.

II. SYSTEMS FOR LFC

The prime mover adjusts its speed whenever there is an imbalance in the load to counteract the impact. The frequency also is influenced by such load imbalance. This variation in speed is managed by the generator governor. The governor speed is set to a constant after the speed change is eliminated. Because load governor speed varies and cannot be fixed to a single value, a secondary control mechanism that uses an integrator is used to eliminate offset and return the system to its reset point. Thermal power systems with three and five areas have been regarded as test systems to verify the functionality of the controllers that were created. Fig. 1 displays the block diagram for the three area power system. A block schematic of the five area power system is shown in Fig. 2. Area control error is caused by any imbalance in the power production and load (ACE). To remove the area control mistake mentioned in (1), a controller is used.

$$ACE_i = B_i \Delta F_i + \Delta Ptie_i \quad (1)$$

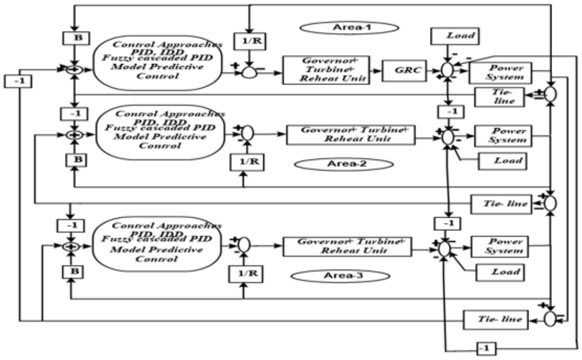

Fig. 1. Block diagram/three area power system.

III. CONTROL APPROACHES

There is a significant function that the secondary control strategy plays in LFC in order to restore frequency and tie-line power to their normal levels. In the past, several methods have been used, shown in Figures 1 and 2, respectively.

Fuzzy cascaded PID control scheme

A fuzzy logic controller (FLC) is a controller that is based on fuzzy logic and provides a mechanism that turns the expert knowledge-based language strategy into an automated control strategy.

FLC includes deffuzification, knowledge base, fuzzy interface, and fuzzification (Fig. 3). This work takes seven triangle type membership functions for each input (Fig. 4). In Fig. 5, the input and output surface diagrams are shown. According to Table 1, 49 fuzzy rules were chosen for the input-output connection based on the seven membership function.

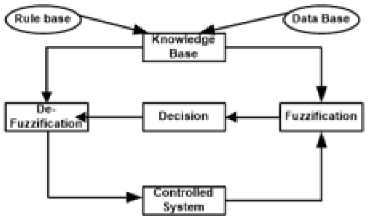

Fig. 3. Block diagram representation of FLC scheme.

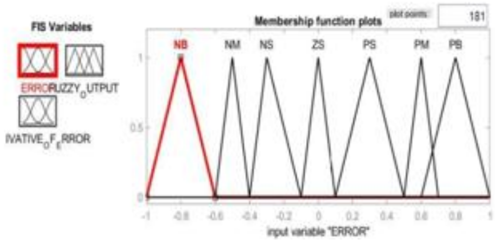

Fig.4. Membership function for load frequency control.

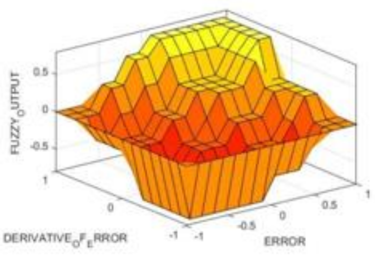

Fig. 5. Surface Diagram of input and output.

The normal and the derivation of area control error (ACE) and (dACE) have been used as inputs to the fuzzy control scheme in this work. The output of this scheme has been compared with the deviation in frequency. This work was carried out for the fuzzy cascaded PID control scheme that is shown in Figure 6. For the purpose of achieving the best possible output, the error serves as an input to the PID control.

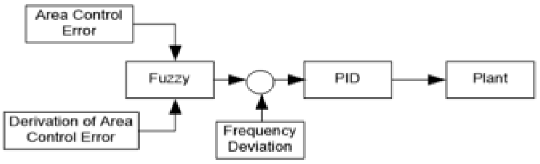

Fig. 6. Block diagram of Fuzzy cascaded PID.

The detail explanation on fuzzy control can be referred from [19-20].

PID and IDD Control schemes

PID and IDD control schemes have also been designed for the given test systems. A well-known BBBC algorithm is used to decide parameters of both the control approaches by minimizing fitness function given in (3). The structure of PID and IDD control schemes is given in Figs. 7-8.

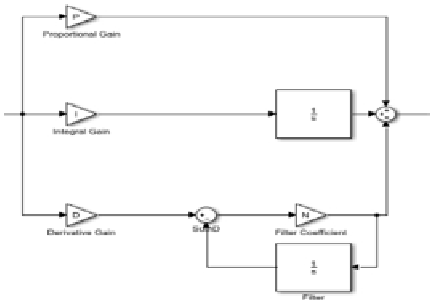

Fig. 7. Simple structure of PID scheme

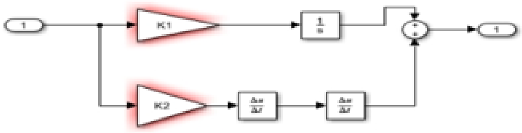

Fig. 8. Simple structure of IDD scheme

$$F=\frac{1}{m}\sum_{i=1}^{m}[(ACE_i)^2]=\frac{1}{m}\sum_{i=1}^{m}[(B_i\Delta f_i+\Delta Ptie_{i\text{-error}})^2]$$

(3)

Model Predictive Control Scheme

Easy calculation, real-time implementations, inclusion of delays, and the ability to handle restrictions are some of the reasons why the MPC control scheme has been employed as a suitable control application in industries [21]. The construction of the MPC that was used in this investigation is shown in Figure 9. On the basis of past-present input/output (I/O) and future control actions, MPC makes predictions about the future output of the system. There are two primary components of the prediction, which are free and forced reactions. Both of these answers are necessary for the entire forecast. In addition to this, the optimizer determines the optimal future control by minimizing a cost function that is subject to restrictions. Using the least amount of control possible, MPC reduces the amount of error in it.

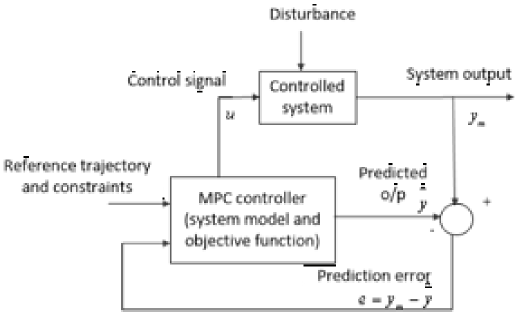

Fig. 9. Simple structure of MPC scheme.

The objective function that is optimized by MPC is given as:

$$J(L_1, L_2, N_u) = \sum_{j=L_1}^{L_2} \alpha(j)\left[y(k+j|k)\hat{} - w(k+j) \right]^2 + \sum_{j=1}^{N_u} \beta(j)[k+j-1]^2$$

(4)

where, L1/L2 are lower/upper prediction horizons, Nu/control horizon, - /weighting factors. / trajectory over the future horizon. consists of the relation that is used to provide the number of future control. The limits on both the control and the output are presented in (9). There is a reference to [21] that provides a comprehensive description of the MPC system.

$$u_{\min} \le \Delta u(k) \le u_{max}$$
$$y_{\min} \le \Delta y(k) \le y_{max} \qquad (5)$$

IV. FINDINGS

On the basis of Figures 1 and 2, the aforementioned strategies have been developed for AGC systems that cover three and five areas respectively.

Step load perturbation in three areas system

A 1.2 pu step load has been considered in both places in this scenario. The frequency of area-1 and area-2 on a load perturbation differs from its nominal value, as Fig. 10 illustrates. In order to return frequency to its planned value, LFC starts a generation shift. There are oscillations in the frequency differences between area-1 and area-2 for every controller. On the other hand, both deviation zones are promptly eliminated using the MPC control method. The changes in area control error, tie-line flow, and generation are shown in Figures 10 and 11, respectively. It is evident that the tie-line flow variance and each location's Gencos instantly went back to the intended levels.

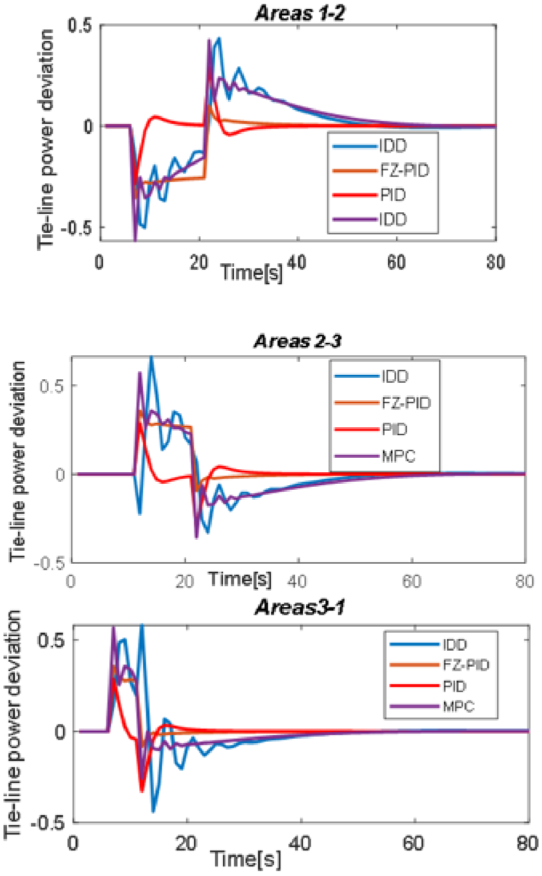

Fig. 10. Tie-line power Flow.

Step load perturbation in Five areas system

In this instance, 1.2 pu of step load has been considered at each position. The changes in area control error, tie-line flow, and generation are shown in Figure 11. It is seen that in steady state, the variations in Genco, frequency, and tie-line power have decreased.

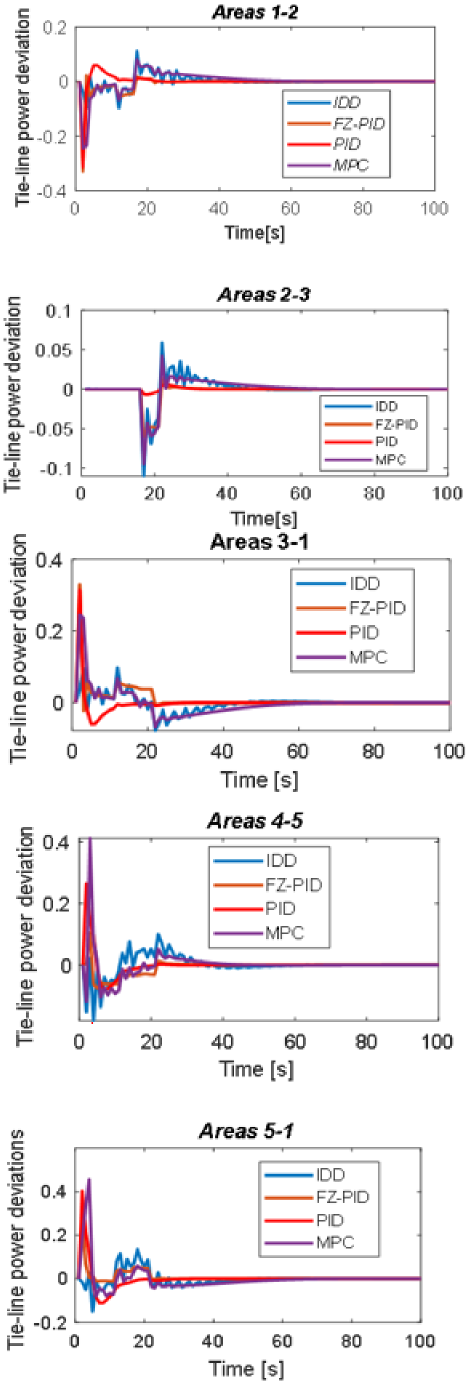

Fig. 11. Tie-line power Flow.

VI. CONCLUSION

For the purpose of this paper, the findings of a study that investigated frequency deviation in thermally connected power systems with three and five areas and a variety of control strategies are presented. A great number of differences in load have been taken into account. A step load shift in areas 1-2 of the three area power system was one of the primary considerations that was taken into account. The second instance is a step load perturbation that occurred in regions 1–5 of the five locations that were investigated. Different control techniques, such as PID, IDD, fuzzy PID, and MPC, have been developed by the authors for the instances that were shown before.

It has been found that the target function for developing PID and IDD control is to minimize the amount of error brought about by the control of the area. It was via the use of the BBBC method that the optimal controller settings were attained. In the process of designing a fuzzy control system, both ACE and dACE have been taken into account as input conditions. In addition, an MPC control technique has been devised by making use of the prediction and control model of a power system that serves two large areas. The dynamic behavior of ACE, tie-line power, frequency, and generation are taken into consideration while analyzing the output of each controller in time-domain simulations.

In Tables 2 and 3, a comparison of the results obtained via the use of each of the approaches is shown. The comparison demonstrates that, with the exception of a few rare examples of bigger oscillation magnitudes, the fuzzy cascaded PID-based control scheme provides better time-domain properties (overshoot/undershoot and settling time), and therefore have the potential to be a valuable choice for an AGC/LFC control system.

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