Grenze International Journal of Engineering and Technology, Jan Issue

Stability Analysis of Multi-Source Power Generation Systems with Automatic Generation Control using Fuzzy Logic Control and I Controller under Load Variation

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***Abstract*— High Penetration of renewable energy with conventional power system increases the system instability problem during recent year. Load frequency control (LFC) is a valuable part in controlling the smart power system. In this paper create a model for automatic generation control with wind power system using fuzzy logic controller (FLC) in single area power system. It is very important to control the integral load frequency while generating thermal and wind. In this paper integral controller is used to obtain the value of FLC. All FLC controllers are to be analyzed and ultimately compared with existing controllers. And finally, it is proved that the calculation done on the basis of FLC is much better than the existing control schemes.**

***Index Terms*— Wind power generation, AGC, Fuzzy logic controller, I Controller, Stability Analysis.**

I. INTRODUCTION

Controlling the power output by changing the system frequency when the load changes is called Load Frequency Control (LFC). LFC is a part of automatic power control (AGC) used in power generation and control [1]. It is very useful in power systems to activate the original output from the generating units which are intrinsically linked after variation in the frequency of the system and equal power replacement.

By implementing specific control methods that are employed in the design of LFC, the dynamic performance of the system is developed. Among many other kinds of LFC, straightforward conventional controllers are frequently utilized [2]. Because of their ease of realization, inherent qualities, low cost, and simplicity, these straightforward controllers are well-known in industries. In order to obtain the Area Control Error (ACE), which is a combined version of errors in frequency exchange of net as the signal for controlling purpose, the integral scheme for controlling in conjunction with conventional scheme are primarily used in the power industries. The traditional approach using the proportional integral controller typically results in bigger overshoots in the transient frequency deviation. Additionally, fixing the frequency deviation takes a lengthy period [3]. Although conventional controlling schemes are frequently employed as secondary schemes and are well recognized for their simplicity, they cannot be guaranteed to provide a superior response that is dynamic in some circumstances [4].

Grenze ID: 01.GIJET.10.1.13

Mishra and Nanda described the AGC computation, which uses both traditional integrals and fuzzy controllers. A location addresses a cohesive group of generators, meaning that their f-frequency deviations are equivalent. Automatic load frequency control (ALFC) refers to the problems with the output power of electrical generators at a specific location due to variations in the tie-line and frequency to ensure the maintenance of interchange and scheduled frequency between other locations.

In remote and rural places where installing electric lines is challenging due to price, right of way restrictions, or environmental considerations, wind power resources are the most cost-effective source of electrical energy [6]. Diesel generators are typically used to create wind resources since they are unpredictable or fluctuate in nature. High reliability is provided by the wind-diesel power generation to increase power to the isolated load. Nevertheless, because the active power requirements of the isolated community vary often, the huge and severe variation of frequency is brought on by the disparity between the generation and load. System device will be disrupted if the deviation could not be controlled and kept within the permissible range. Additionally, the system can become unstable [7].

In AVR and AGC, fuzzy logic controllers are used. Analysed are a large number of triangle-shaped membership functions (MFs) that provide a good response. Fuzzy PI controller has the following benefits: (i) it provides a better approach to copy with incorrect information; (ii) it allows for flexibility in decision-making; and (iii) it provides a good machine/human interface by adopting a human rule for extracting information and by following a logic for the explanation's conclusion [8].

In section (2) explain single area system in thermal, wind briefly with problem formulation. Optimization technique (Fuzzy logic controller) explain in section (3). Finally result analysis and conclusion briefly explain in section (4) and section (5).

II. SINGLE AREA SYSTEM

A. Thermal power system

The steam produced in the boiler flows to the turbine blades, where it is converted into mechanical energy, in the thermal model that is being discussed here [1]. This model was chosen for ease of comparison and execution. This energy is changed into electrical energy by employing a generator. Thus, the steam turbine is the focus of the thermal power plant concept. Open loop systems are not employed because the power supply exhibits frequency variations and an erratic nature without a controller. The proper controller gains are used with closed loop systems. single area thermal system is perturbed by 1% steps. Without a controller, the thermal system's reaction is unstable, thus an integral controller value is computed (K_i=0.047) through trial and error. After the influence of the controller, the controller significantly increases the system's stability, and the system is approximately stable at 19s, with a pear over shoot of -0.043.

B. Wind power system

In ref, the transfer functions of wind power system operations with and without pitch controls are primarily investigated. Without the pitch controller, there will be greater variations in a typical step disruption. The fluid coupling serves as the tie line foundation in this arrangement. The change in power is the result of fluid coupling and frequency variation. This is seen as a feedback reaction that links the two systems. The thermal system receives 1% of the step disturbance for each individual reaction. The specifics of a wind system's architecture have already been covered in ref. [9]. The response of a wind system without a pitch and I controller is examined there as well [10]. Changes in wind speed create steady-state errors of 0.052 magnitudes and oscillatory responses from the wind system for both disturbance signals. In order to maintain system stability and prevent wind system components from being harmed by excessive wind speed variation, the steady state error must be under control. There are no matches between the load and generation under standard processing circumstances. The production as a whole is given by Equation (1)

$$P_G=P_{Gth}+P_{GW} \quad (1)$$

Where: P_{Gth} = K_{th} P_G, P_{GW}= K_w P_G K_{th} and k_w stand for the proportions of thermal and wind power generation to total power generation, respectively. The total load dispatch affects the values of Kw and Kth. Equation (7.1), for small perturbation, can be written as:

$$\Delta P_G=\Delta P_{Gth}+\Delta P_{GW} \quad (2)$$

From equation (7.2), under normal operating condition and loading P_G=P_L=1.0 P.U, we have

$$K_{th}+K_w= 1.0 \quad (3)$$

By adjusting the speed-varying signals, the ungoverned system becomes governed. It is believed that the automatic manipulation of P_{Cth} and P_{CW} by thermal and wind power plants helps to control load frequency. The thermal system and the wind system were initially investigated individually in this paper, both with and without a controller. The performance of the system was also examined, even when the system loads and parameters were changed.

III. Fuzzy Logic Controller

The FLC architecture can be broken down into three categories: allocating inputs to certain regions, figuring out the rules associated with inputs, and defuzzing output to its original value [11]. Determining the process states and control output: The initial stage focuses on choosing the appropriate input signal for the fuzzy logic controller. The content of the rule base antecedent is represented by a selection of process state variables for this controller.

- ACE and ACE change. ACE versus ΔACE
- ACE and change in frequency (ACE Vs Δf)

ACE and change in ACE are selected for the controller created for automatic generation control.

Fuzzy rules: The guidelines used when employing fuzzy controllers are listed in the table 1. The following examples show how the rules work: if ACE is NLa and ACE is NLa, ACE-out is NLa; if ACE is NSm and ACE is NLa, ACE out is NLa; etc. The "Mid-max" rule for "and" and "or" was implemented in the formula as a result. The challenges resulting from measurements and time are reduced to a minimum with this method. Since they differ from the norms, ACE is given far more attention than ACE. As a result, the ACE location with greater influence in this region is allowed to have a dead band on a variation basis.

TABLE 1: Rule base for Thermal, wind and Thermal+Wind system

DEL ACE \ ACE	**NLa**	**NSm**	**ZEr**	**PSm**	**PLa**
NLa	**NLa**	**NLa**	**NSm**	**NSm**	**ZEr**
NSm	**NLa**	**NLa**	**NSm**	**ZEr**	**ZEr**
ZEr	**NSm**	**NSm**	**ZEr**	**PSm**	**PSm**
PSm	**ZEr**	**PSm**	**PSm**	**PLa**	**PLa**
PLa	**ZEr**	**ZEr**	**PSm**	**PLa**	**PLa**

Numerous membership function types, including triangle, bell, trapezoidal, and Gaussian, are available in fuzzy logic inference systems. The rule base and membership operations are tightly related. In Automatic generation control (AGC), the FLC must react more quickly to every change in the ACE. Flow Chart for the Proposed FLC in Thermal+Wind generation system as shown fig. 1

IV. Result Analysis

The effectiveness of a single area has been discussed how to use a traditional I controller, a fuzzy logic controller, and a MATLAB SIMULINK model for a thermal, wind, and thermal+wind system. A controller for fuzzy logic with input, output, and feedback gain. FLC analysis demonstrates that it enables quick and effective dynamic reactions. The optimal gain K_t for the thermal area of the 5-membership function is 0.07, while the optimal feedback gain K_t for the wind area is 0.01, respectively. The FLC is superior, as can be seen from the comparison of the traditional I controller in the following figure 2, 3, and 4. The FLC requires less time for settling than the traditional I controller.

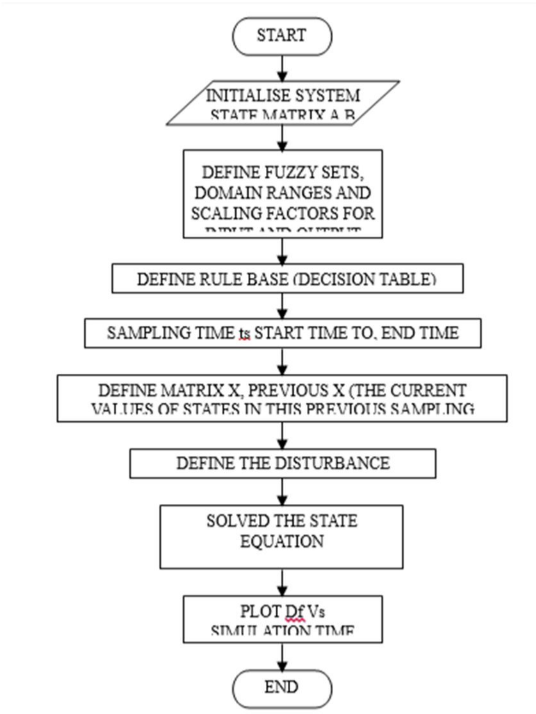

Figure 1 Proposed Flow chard for FLC in Thermal+Wind system

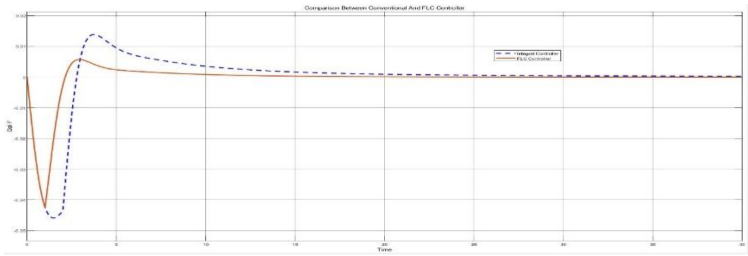

Figure 2 Performance comparison for a single area thermal system using conventional and FLC controllers

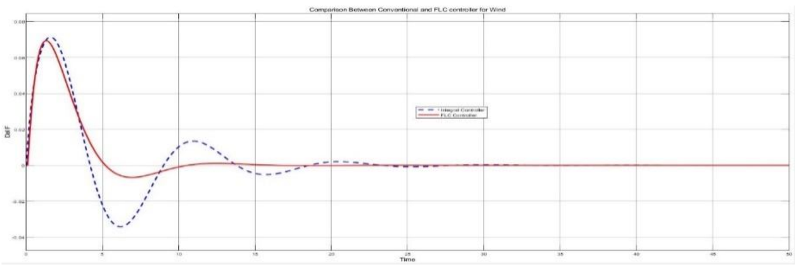

Figure 3 Performance comparison for a single area Wind system using conventional and FLC controllers

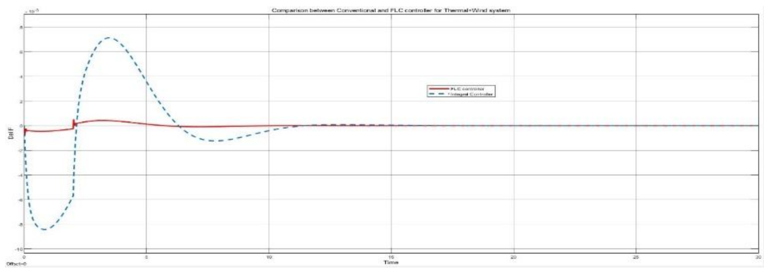

Figure 4 Performance comparison for a single area Thermal +Wind system using conventional and FLC controllers

Table 2 clearly proves that an FLC-based integral controller performs better when compared to a traditional controller by displaying the time required for peak settling and overshoot in a thermal, wind and thermal+wind system located at a specific location.

TABLE II: ANALYSIS BETWEEN CONVENTIONAL I CONTROLLER AND FUZZY LOGIC CONTROLLER

S. No.	Systems	Parameters	Conventional I Controller	Fuzzy logic Controller
1	Thermal power system	Settling Time (Ts)	24 Sec	13 Sec
		Peak overshoot (Ms)	0.044	0.04
2	Wind power system	Settling Time (Ts)	23 Sec	11 Sec
		Peak overshoot (Ms)	0.078	0.064
3	Thermal+Wind power system	Settling Time (Ts)	13 Sec	10 Sec
		Peak overshoot (Ms)	0.009	0.004

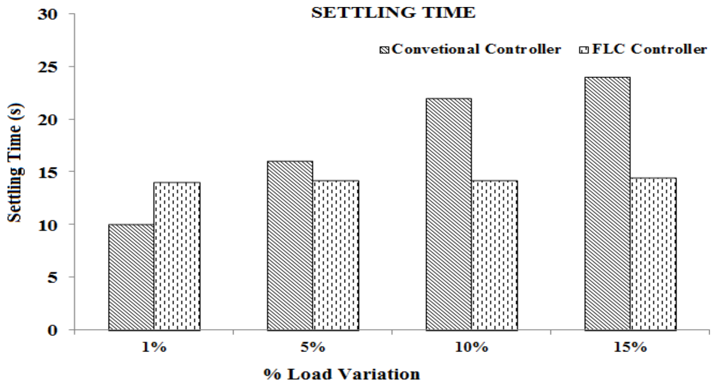

FIGURE 5: Performance comparison of a single area, multigenerational system using conventional and FLC controllers for settling time

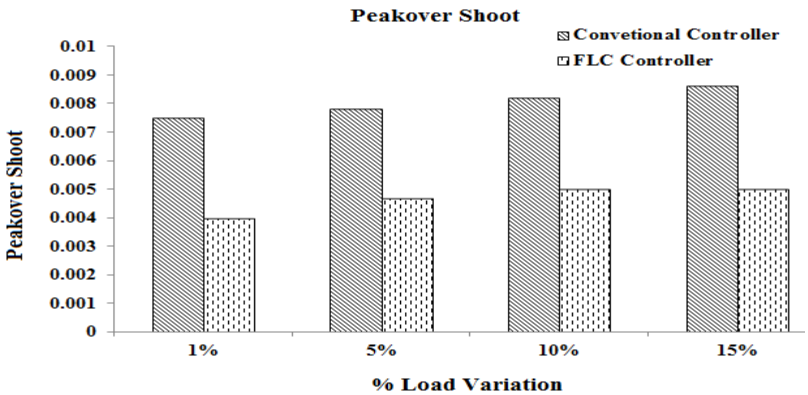

FIGURE 6: Performance comparison of a single area multigenerational system with conventional and FLC controllers for Peak Over Shoot

Simulated integral controller gains for the suggested systems are obtained from the FLC, and the outcome demonstrates the time-domain evolution gradually. It has been demonstrated that the FLC governor in use is more effective than a traditional controller controlled by a Ziegler mechanism. Furthermore, because more system tool knowledge is not required, the suggested controller is simpler and easier to build. The typical area multi-source has been processed for various future generations for a variety of loads with a difference of ±15% and ±15% from the assigned value in both locations, and the scheduled power production from Thermal+Wind system are regulated to adapt with the typical operating load as shown in Fig. 5 and 6.

V. CONCLUSION

The FLC dependent load control of a specific location with thermal and wind resources is examined individually in this study, and the two systems are then combined into a single generator made up of implemented and existing governors. Due to differences in the loads, the controller's traditional integral components need to be adjusted. The transient computation will grow if the wind and thermal productions are higher. The system should be designed to inhibit the dynamics of the power resources in order to determine the gain of the controllers. Results obtained fuzzy logic control structure used for load frequency control for the single area power system its supremacy over the conventional controller.

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