Enhancing Load-Frequency Control in Hydro-Thermal Power Systems with Wind Farm Integration using Fuzzy-PID Control via HVDC Lines

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Abstract-Stable frequency maintenance is essential for contemporary linked electrical power networks. In order to guarantee that the frequency deviation stays constant despite ongoing load fluctuations, load frequency control, or LFC, is essential. The optimization of LFC for a two-area power system with various control schemes is the main goal of this research. Maintaining the frequency deviation when various sorts of areas are interconnected is the primary function of the load frequency control.The many forms of energy produced cause the frequency to become unstable, which might result in Here, we employed a variety of controlling techniques. In order to manage the frequency change close to the stable frequency and optimize the PID values for better performance, we employed fuzzy-PID and PID controllers together with algorithms.To improve the PID values, we employed genetic algorithms (GA). In order to increase the system's economy and efficiency, we must use controllers and optimization techniques to enhance its performance. To ensure steady power system performance, load frequency control, or LFC, is essential. It guarantees that even under different load situations, the frequency deviation stays within allowable bounds. To improve LFC performance, researchers have recently investigated a variety of optimization strategies.

Keywords—Load Frequency Control (LFC),Fuzzy Control, Fuzzy-Pid, Genetic Algorithm(GA)

I. INTRODUCTION

Maintaining stable frequencies is crucial for modern interconnected electrical power networks. Load frequency control, or LFC, is crucial to ensuring that the frequency deviation remains stable despite continuous load fluctuations. The primary objective of this research is to optimize LFC for a two-area power system with different control strategies.The main purpose of the load frequency control is to maintain the frequency deviation when different types of regions are connected.The frequency becomes unstable due to the various sources of energy created, which could lead to We used a range of controlling strategies in this instance. We used fuzzy-PID and PID controllers along with algorithms to manage the frequency change near to the stable frequency and improve the PID settings for better performance.A comprehensive review of the literature on AGC in power systems, encompassing numerous LFC control domains, has been released.

However, many modern methods, such as the ones mentioned above, require a level of expertise that limits their usefulness. Therefore, it is advised to use conventional PI and PID controllers due to their advantages, which include their high performance and simple design. Moreover, some publications use clever algorithms to maximize the PI/PID controller settings. The control areas that made up the power systems were connected by transmission lines. Sustaining frequency stability is necessary for enhanced power system performance.For power plant generators to be long-lasting and have frequency stability, the load control loop is essential. The speeds of the synchronous and induction motors are stabilized using frequency control. In the past few years, there has been a significant increase in the use of renewable energy sources like wind and hydropower in electricity networks. The productivity of hydraulic plants can be determined by altering the water turbine's intake valve. The integration of a wind farm into the electrical grid will complicate frequency regulation. Wind farm productivity is influenced by wind speed, which causes frequency fluctuations in the power system. The controller needs to be utilized in a load-frequency control loop with a fast reaction time in order to maintain the system frequency within the bound. Research on load-frequency controller design in power systems can be divided into four categories: adaptive control, intelligent control, resilient control, and classical control approaches. This section looks at some of the most anticipated works from the previous several years.

II. FORMULATIONOFTHE PROBLEM

For LFC research related to the power systems, an accurate model of every functional component is required. The model of the power system under study is shown in this part, followed by the proposed fuzzy-PID controller. Finally, the proposed objective function (OF) is provided. The transfer function of the two-area power system under study is shown in Figure 1. There is one thermal unit and one hydro unit every ACE area. The anticipated system transfer function is shown in Figure 2.

THE PROPOSED CONTROLLER

The suggested controller is a fuzzy PID hybrid control, which uses the Relevant power system model (FIG-1) to account for fuzzy components and controller values.

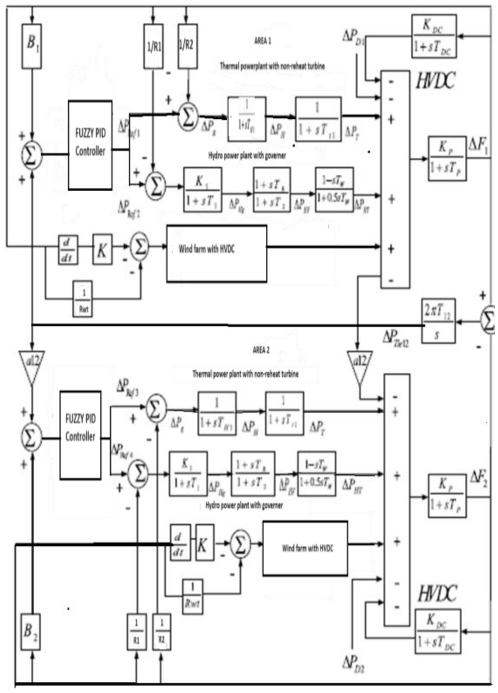
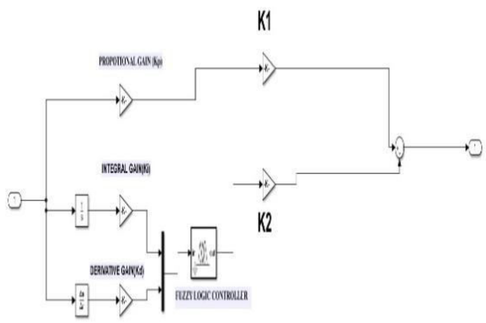


FIG-1:- Relevant Power System Model

The proposed F-PID controller is shown in FIGURE 2.



FIG–2:-Proposed F-PID controller

Fuzzy controllers serve as dependable stabilizers in power systems during fading. of order to stabilize the frequency of the system under investigation, this work looked at using a fuzzy PID controller. The fuzzy PID controller coefficients are adjusted using fuzzy logic in accordance with the suggested controller performance [52]. When a fuzzy controller is used before a PID controller, its purpose is to enhance performance by adjusting the PID control coefficients under different loading conditions.

$$ACE_i = B_i \Delta f_i + \Delta P_{tie}$$

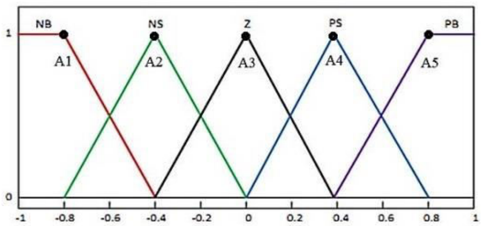


FIG-3 TWO INPUTS AND ONE OUTPUT MEMBERSHIP FUNCTIONS

Three membership functions for the controller's inputs and outputs are shown in Fig. 3: trapezoidal (NB and PB) for applied large negative and positive changes, and triangular-type (NS and PS) for applied little negative and positive changes.
The range of changes for these five coefficients is displayed in Table 1.

Table – 1 Variations in the fuzzy control coefficient range.

Coefficient	A1	A2	A3	A4	A5
Interval	[-1 -0.5]	[-0.5 -0.1]	[-0.1 -0.1]	[0.1 0.5]	[0.5 1]

Fuzzy rule for the proposed controller is given in Table-2

Table-2:-Fuzzy-PID controller fuzzy rule table.

ERROR (E)	CHANGE IN ERROR ($\bar{E}$)				
	NB	NS	Z	PS	PB
NB	NB	NB	NB	NS	Z
NS	NB	NB	NS	Z	PS
Z	NB	NS	Z	PS	PB
PS	NS	Z	PS	PB	PB
PB	Z	PS	PB	PB	PB

The goal of this work is to control a two-area thermal system's load frequency using a genetic algorithm. GA The PID controller settings are also managed by PSO. Its specifications Utilize the proportional constants Kp, KI, and Kd to reduce the error function. The Integral Time of Absolute Error (ITAE) is the error function used in this work. The formulas are

$$J = \int_0^{t_1} (|\Delta f_1| + |\Delta f_2| + |\Delta p_{tie}|).t$$

$$\Delta f_1^{min} \leq \Delta f_1 \leq f_1^{max}$$

$$\Delta f_2^{min} \leq \Delta f_2 \leq f_2^{max}$$

$$\Delta p_{tie}^{min} \leq \Delta p_{tie} \leq \Delta p_{tie}^{max}$$

Where

Δf_1 = change in frequency of area-1

Δf_2 = change in frequency of area-2

Δp_{tie}= change in tie line power

III.Techniques for Intelligent Control

The mathematical technique of finding a function's minima and maxima under specific constraints is called optimization.These days, optimization encompasses a variety of To improve business processes across industries, a variety of approaches from computer science, artificial intelligence, and operations research are applied.Finding the best answer is the process of optimization.The goal of mathematical programming, sometimes referred to as optimization modeling, is to determine the best possible answer to an issue. Numerous approaches have been proposed to control this issue.

The difficulties in LFC lie in creating a dependable controller and properly adjusting its parameters to achieve the best outcomes.LFC problems are solved using a variety of optimization techniques, including as GA, PSO, BFO, DEA, ANN, FLC, and others. This thesis addresses frequency and tie line power variations and suggests a Genetics Algorithm (GA) based PID controller to solve the optimal LFC problem.

A.GENETIC ALGORITHM

A probabilistic search technique that computationally simulates biological evolution is called a genetic algorithm. The following flowchart provides an overview of the steps the algorithm takes.This method, which iteratively refines a set of viable solutions until the optimal one is found, is similar to natural evolution. Starting with an initial population selected at random, the GA evolutionary cycle commences. In addition to mutation and crossover, fitness-based selection also plays a role in population evolution.A population with more superior answers can be produced through the use of selection and transformation.

Until a workable solution is discovered in the present generation or a regulatory limit, such the number of generations, is exceeded, the evolutionary cycle keeps on. In a genetic algorithm, a gene is the smallest unit that represents an information unit inside the problem domain. A chromosome is a group of genes that offer one potential fix for an issue. A component of the solution pattern is represented by each gene on the chromosome.

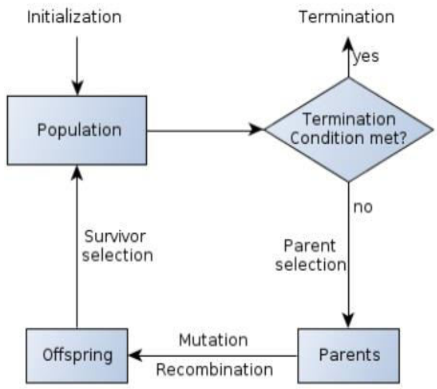


FIG – 4. Flow Chart Of GA

Binary integers are the most common approach to represent a solution as a chromosome. In this string, every byte corresponds to a gene. The method for changing the solutionThe process of translating a distinct format into a bit string is called coding. The particular coding method used depends on the application. A fitness measure is used to evaluate the cracked solution bit strings.

(i) Selection: In biological evolution, the more fit individuals endure and disperse their genes to progeny. In GA, selection works in a similar way. Chromosomes are chosen by fitness proportionate selection in accordance with their fitness value.

(ii) Crossover-crossover is a type of artificial mating that involves combining chromosomes from two individuals to generate a new chromosome generation. This involves splicing two chromosomes from separate solutions at a crossing location and switching the resulting sections. Combining excellent genes from one chromosome with those from another can result in a more effective solution represented by the new chromosome.

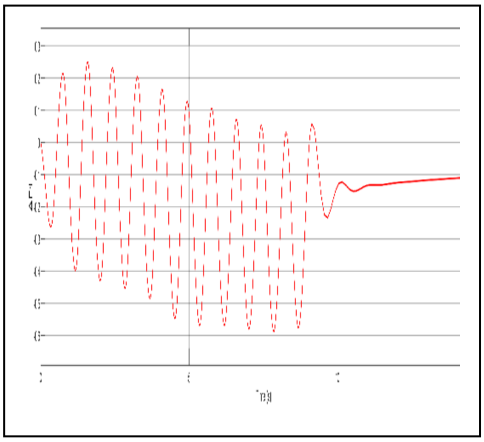
(iii) Mutation is a random change to the genetic makeup. This method is useful for identifying novel traits in a population, which cannot be obtained with only crossover. Crossover just rearranges existing traits to create new combinations.

IV. SIMULATION RESULTS

In this paper, using the suggested PID controller is proposed to control the multi-area power system frequency with thermal, hydro and wind units. For optimal designing of the PID gains in controller was applied by Genetic Algorithm In this article, the suggested controller performance designed in two-area power system, with 10% load variation in each area is evaluated. It was compared with other controllers and also various algorithms.

Matlab implementation of two areas (Thermal-Hydro) load frequency control system area control error which is equal to sum of deviation in tie-line power and deviation in area frequency multiplied with frequency bias constant, together with its derivative ACE have been considered as inputs to Genetic algorithm optimization controller. The thermal-Hydro system is MATLAB implementation.

The embedded MATLAB function only having two inputs first is direct input and second is delay input by last output. MATLAB function is only taking average of these two values so the output function Y is evaluated. This function gives the set value at the time of variation and gives system stability. This MATLAB implementation of two area load frequency control study in different case like tie line bias control, Ziegler-Nichols method and PID tuned GA method.



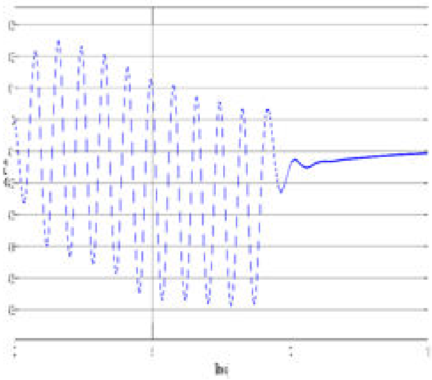
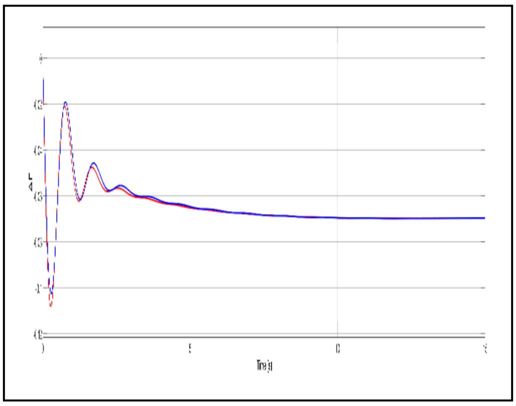


Fig – 5 Frequency Deviation of ΔF1,ΔF2 of the system using Fuzzy – Pid Controller



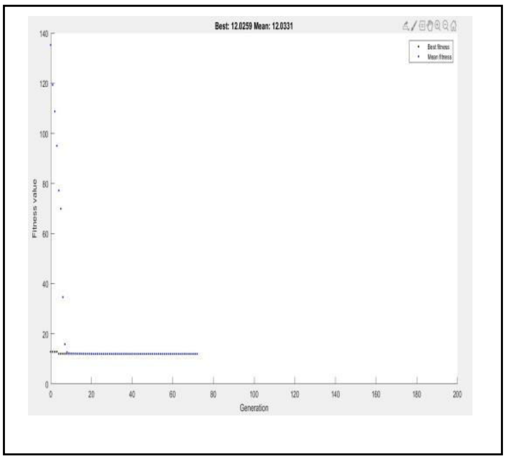


Fig – 5.1 Frequency Deviation of ΔF1,ΔF2 of the system using GA – Pid Controller

Fig – 8 Genetic Algorithm

S.NO	Controller / Observed Parameter	WITHOUT CONTROLLER	WITH FUZZY-PID CONTROLLER	WITH GA-PID	WITH PSO-PID
1	ΔF1	-0.3934	-0.1066	-0.06961	-0.09834
2	ΔF2	-0.1102	-0.1057	-0.6961	-0.09074
3	ΔPtie	-0.7603	0.0004016	-0.003106	-0.2703
4	ITAE	92.44	40.2	15.66	21.88
5	ΔPD1	0.1	0.1	0.1	0.1
6	ΔPD2	0.1	0.1	0.1	0.1

Table - 3 Results For Different Controlling Techniques

V . CONCLUSION

This work proposes an optimal PID controller for the frequency regulation of the multi-area power system with hydro-thermal units linked to the wind farm. The membership functions and suggested controller parameters are created. Wind farms are used in a single scenario for simulations. Several types of controlling techniques are used in the situations in this project.Outcomes from the various controllers are observed. In comparison to other controlling techniques, the aforementioned project's use of a genetic algorithm produces superior outputs with steady state error, than a fuzzy-pid controller. Much better results are obtained using the genetic algorithm: ΔF1 = ΔF2 = - 0.06961, with a 10% load variation. The PID settings are optimized for the optimization using the algorithms.

The optimized GA-PID has an ITAE Value of 15.66.Since these sources will supply a portion of the power deficit by abruptly boosting the demand in a brief amount of time, the system's frequency deviation will decrease. However, conventional controllers like PID in nonlinear systems, like the power system under study in this paper, performed poorly, and when they were utilized in a load control loop, the frequency amplitude was large. Dampening also requires more time. Amplitude and settling time will go down if nonlinear controllers, such as fuzzy controllers, are used.

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