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A STUDY OF ANN BASED LOAD FREQUENCY CONTROL FOR TWO AREA POWER SYSTEM

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Abstract: In this study, load frequency control (LFC) of a two-area power system by using an artificial neural network controller (ANN) is presented. The comparison between conventional controller, Fuzzy Logic Controller (FLC) and proposed ANN controller is showed that the proposed controller can generate an improved dynamic response. The application of neural control to lessen load frequency fluctuations is described in this work. A MATLAB environment has been used to simulate a power system model. A comparison of the frequency response of the system with a neural controller trained with the Levenberg-Marquardt method as well as PID and FLC controller has been conducted. In terms of peak overshoot, settling time, and ease of implementation, the neural controller declares its superiority over a conventional controller.

Keywords: Load frequency controller, power system, fuzzy logic controller, artificial neural network, Levenberg-Marquardt

1. INTRODUCTION

The variation in system frequency affects not just the local community but also the social and economic facets of society as a whole, necessitating worldwide attention. The system's most prevalent loads are induction motors. Since an induction motor's speed and torque are related to the system frequency, variations in the frequency of the system may result in unintended changes in productivity. In power systems, synchronous generator control and stability augmentation are crucial. In the past, several controller types based on "classical" linear control theory have been created. The LFC, is crucial to a power system's ability to facilitate power exchanges and provide improved trading conditions for energy. Furthermore, time delays in these systems can impair system functionality and perhaps result in instability with regard to frequency or other parameters. When a power plant trips or there is an increase in load, the system frequency changes. This is initially compensated by a decrease in kinetic energy using the system's momentum, and it continues this way until the speed sensors, governors, amplifiers, and actuators take some time to react to the load change. For power systems to deliver dependable, high-quality electricity, load frequency regulation is crucial. Maintaining zero errors in steady state in a multi-area linked power system is the aim of the LFC.

Numerous studies on load frequency management have been conducted in the past. Certain control strategies that are based on the traditional linear control theory have been proposed in the literature. Because of the complexity of the power system, including nonlinear load characteristics and changeable operating points, these controllers might not be appropriate in certain operating conditions. The system frequency stability is maintained by variable structure control according to most of researchers. To develop an effective controller; one must have a thorough understanding of the system's static and dynamic features. However, managing a system this complex comes with a lot of challenges [6]. Particular attention must be given to the controller design because the dynamic behavior of a power system, even for a simplified mathematical model, is typically nonlinear, time-variant, and influenced by significant cross-couplings of the input variables. Frequency affects the losses and loads in power system. The High frequency deviation could therefore cause the system to collapse. To keep the nominal frequency constant in this situation, a precise and responsive controller is required. Systems with nonlinearities are handled inefficiently and slowly by integral, PI, and PID.

The ANN control has been the new subject of numerous studies. The performance of a PI controller, a neural network that is trained to predict the steady-state result of the PI controller, as well as a combination of PI and neural network is compared using a precise simulation of the heating coil (S.D. Al-Majidi, 2022; N. Kumar,2021).It has been demonstrated that neural network-based PI and PID controllers are designed and simulated to improve position accuracy in a

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pneumatic servomotor. These controllers also have a straightforward structure that makes them easier to implement and operate more efficiently than they would on their own (M. Regad, 2020).However, sudden changes in the system parameters may cause the transient response for that controller to become unstable. Furthermore, it is unable to produce precise linear times for varied models on variable operating points. In this work, an ANN controller is suggested as a solution to all of the issues raised in the papers. By utilizing neural networks' learning capabilities, the ANN controller was developed to apply power system in various operating points under various load disturbances, thereby enhancing the overall system's stability and achieving good dynamic performance.

2. ARTIFICIAL NEURAL NETWORK CONTROLLER

A neural network is a mathematical representation of the brain that mimics how a biological neural network functions. It is made up of a group of neurons called input, output, and hidden neurons. Applications for neural networks include data mining, robotics, recognition, control, and a number of other fields with complicated relationships between input and output, high degrees of nonlinearity, and high dimensionality.

The Adaptive Control setup of the Model Reference makes use of two neural networks: a model network and a controller network. The plant measurements from the past can be used to train the model network offline. The plant output is made to follow a reference model output by means of adaptive training of the controller. By using the model network to forecast how changes to the controller would affect plant output, controller parameters can be updated. The study's neural network controller inputs are selected from among the area's load perturbations, frequency deviations, and tie-line power deviations. A three-layer perception with four inputs, ten neurons in the hidden layer, and one output is also present in the ANN Plant model. Hyperbolic tangent serves as the network's neurons' activation function. The backpropagation technique has been used to train the suggested network. The learning performance is assessed using the root mean equal (RMS) error criterion. Weights are adjusted using learning algorithms in order to get the desired response from the controlled system.

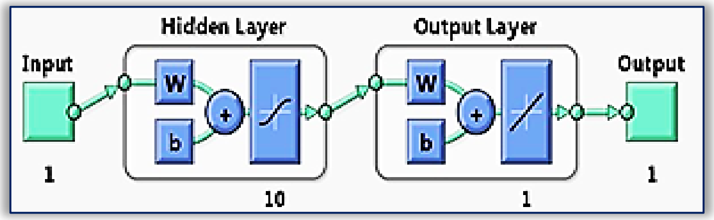

Figure 1: Network Architecture

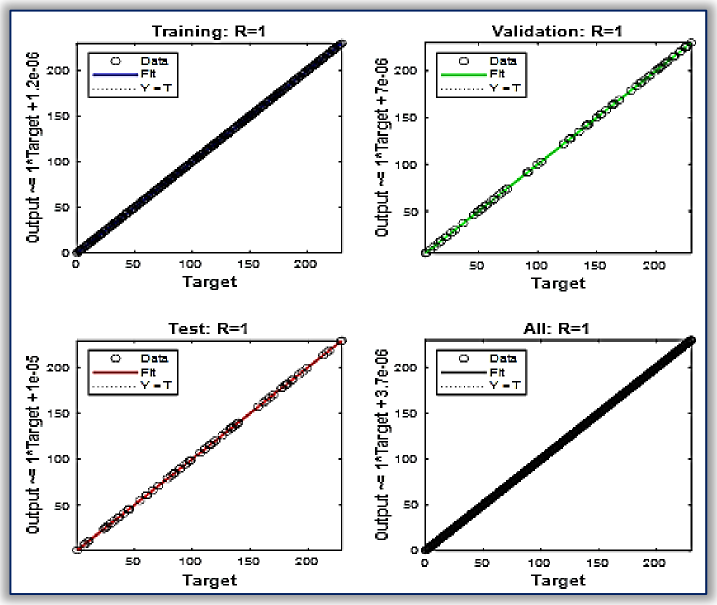

Figure2: Regression Plot

ANN can be used to determine the relationship between input and output with minimal processing overhead and a limited amount of assumptions. This reduces the errors caused by the assumptions and uncertainties in the system parameters. The MATLAB/Simulink software is used to simulate the entire system with a conventional PI controller. Critical load voltage data and pi controller gains are used as input and output data. They are taken from the MATLAB workspace and stored in datasets. During the neural network controller training process in MATLAB, these data sets are sent as input and output matrices to the nn control toolbox.

Increasing the size of the neurons improves the outcomes. However, system performance declines as the size is increased above a certain point. There are ten neurons chosen to be in the buried layer. A two-layered feed-forward network with a linear transfer function inside the output layer and a sigmoid transfer function inside the hidden, concealed layer is shown in Fig. 1.The Levenberg-Marquardt back propagation algorithm is utilized to train the controller. Three groups—Generalization, Validation, and Testing/Training—each with a percentage change—are created

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from the supplied data information. A 70% training set, 15% validation set, and 15% generalization set are often taken into account. Training ends when the controller is made more widely applicable during the phase (D. Xu, J. Liu,2018 ; Atullkhe, 2023).The size of neurons found in the hidden layer that is hidden is determined after the data sets have been divided. In this work, the behavior of a PI controller is simulated using a neural network. Every change in load is received by the neural network as an input, and it generates an output control signal that is required to keep the frequency oscillations stable. One can ascertain the quantity of buried neurons by monitoring the Mean Square Error (MSE). The regression plot helps to understand how close the desired output value from your model is to the target values.

3. TWO AREA POWER SYSTEM MODEL

The complete block diagram of a two area region interconnected power system model is shown in Figure 3. Naturally, complex and multi-variable structures with a wide variety of control blocks comprise interconnected power systems.

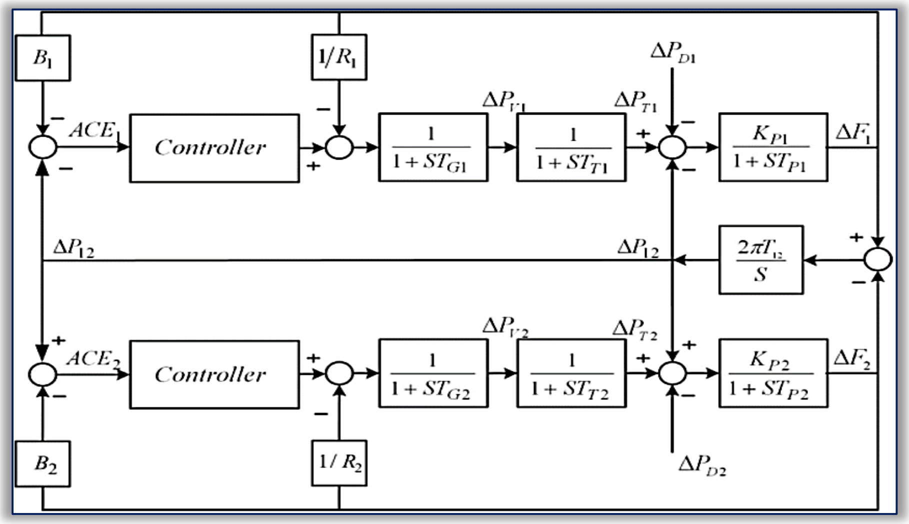

Figure 3: Block diagram of two area power system.

A governor, a generator and a turbine having feedback from a regulatory constant make up a power system in its basic form. Step changing the load input to the generator is also included in the system. The primary focus of this work is the controller unit of a two-area power system. Power systems are separated by tie lines into control areas. In practical use, the speed changer motor is used to adjust the load reference set point. The only way to alter each unit's output at a specific system frequency is to adjust its load reference, which essentially adjusts the speed-drop characteristics up or down. This control operates very slowly and only engages when the primary speed control has finished its task.

The system output, which depends on ACE shown in (Figure 3), is given as,

$$ACE_i = \Delta P_{tie,j} + b_i {*} \Delta F_i \quad (1)$$

where, b_i is the frequency bias constant, f_i the frequency deviation, $\Delta P_{tie,j}$ the change in tie-line powers for area i and C is the output matrix.

It is assumed that each area has a governor-turbine system and a single equivalent generator. These are the signals that the controllers we select send out. Three components make up the plant for a power system using a non-reheated turbine:

— Governor with dynamics: $$G_g(s)=\frac{1}{TGs+1}. \quad (2)$$

— Turbine with dynamics: $$G_t(s)=\frac{1}{TTs+1}. \quad (3)$$

— Load and machine with dynamics: $$G_p(s)=\frac{Kp}{TPs+1}. \quad (4)$$

For load frequency control, the open-loop transfer function without droop feature is now

$$\tilde{P} = GpGtGg = \frac{Kp}{(TPs+1)(TTs+1)(TGs+1)}. \quad (5)$$

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4. MATLAB Simulink Model

In a two area power system, a tie-line connects two single area systems. Having established links increases the system's overall reliability. Even if parts of the generating units in one area fail, the generating units in the other area can compensate to meet the load requirement.

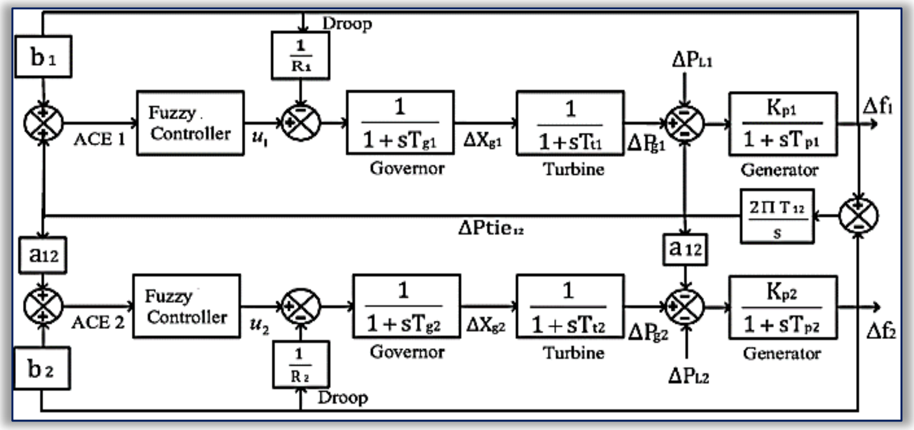

Figure 4: Fuzzy logic controller based two area power system Simulink model.

A conventional integral controller is used on a power system model. A transient reaction with little to no overshoot is allowed by the PID controller by concurrently decreasing steady state error. As long as the error is present, the integral output will increase and cause the speed changer position; it only reaches a constant value when the frequency error has reduced to zero. The implementation of PI, PID and FLC controller is possible in proposed power system is shown in Figure 4. The Figure 5, Figure 6 and Figure 7 displays the output response for area 1, area 2 and tie-line along with comparative findings between proportional integral (PI),proportional integral derivative (PID) and fuzzy logic controller (FLC),FLC produces an output frequency response that is superior to PI and PID.

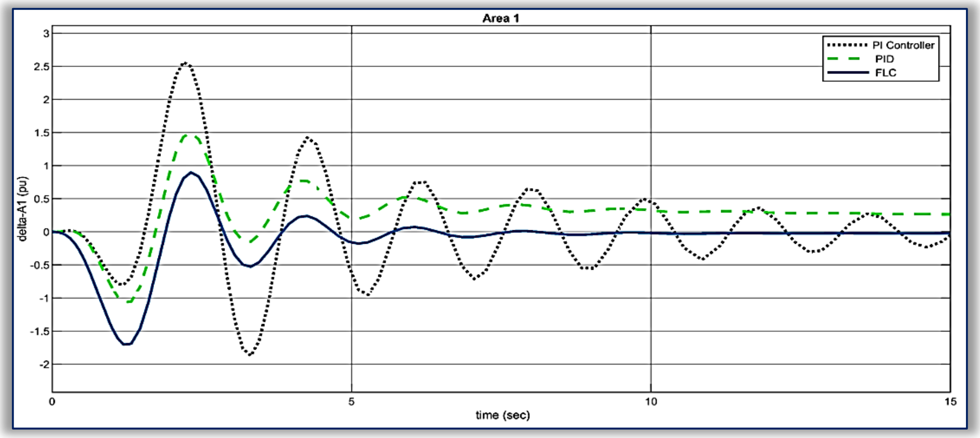

Figure 5: Output frequency response using PI, PID and Fuzzy logic controller for area 1

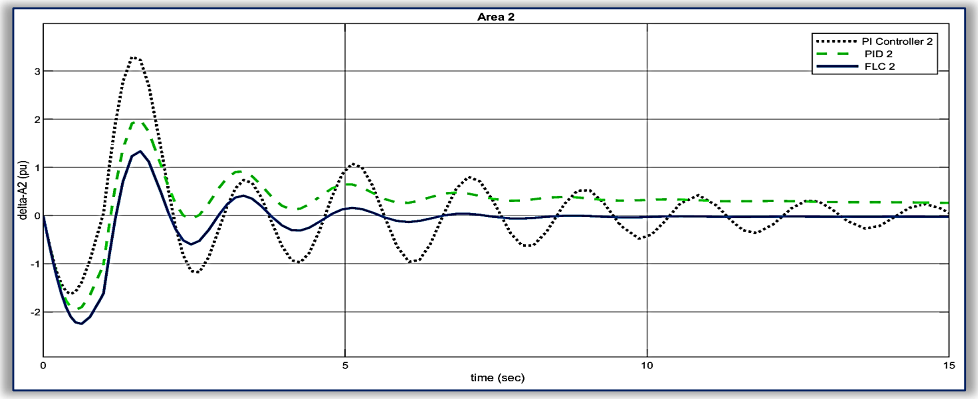

Figure 6: Frequency response for area 2.

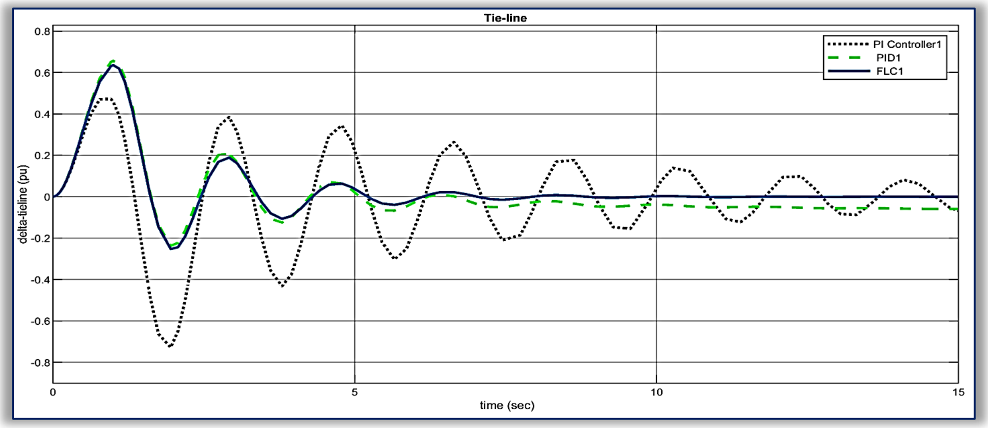

Figure 7: Output frequency response tie-line of power system.

The gain value of different types of controller using in two area power system is given in Table 1.

Table 1: Different values of gain for different controllers

	Kp		Ki		Kd		Overshoot	Oscillations	Settling time (sec.)
Controller	Area1	Area2	Area1	Area 2	Area 1	Area 2			
PI	0.1109	0.0121	0.2742	0.2019	-	-	Peak	More	35
PID	0.1109	0.0121	0.2742	0.2019	0.1110	0.003	Low	Less	25
FLC	--	--	--	--	--	--	Low	Less	8

It demonstrates how various controllers receive varying values for the settling time. FLC controllers settle faster than PI or PID controllers. Using advanced control techniques, we can regulate oscillations, rise time, and settling time. The control signals that are applied to the local governors are the neural network's outputs. The Reference Model Neural Network provides the data needed for ANN controller training, which is then applied to the power system having step response lead disturbance. The implementation of ANN in two area power in MATLAB Simulink model is shown in Figure 8.

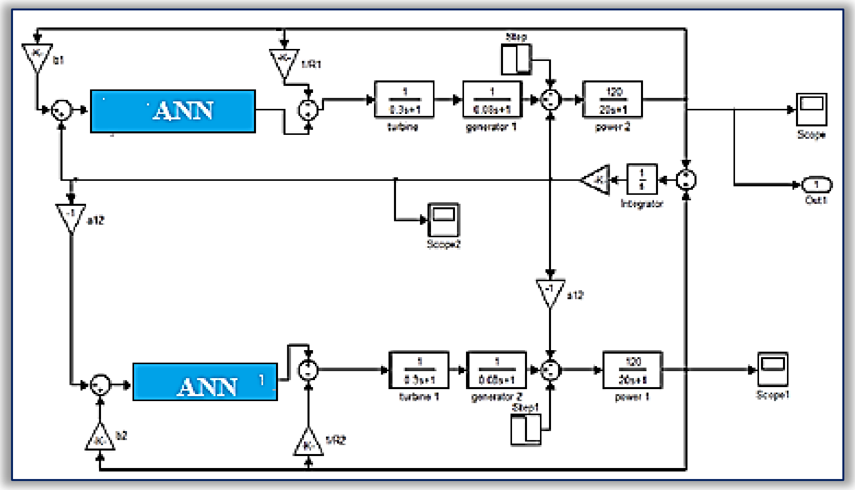

Figure 8: ANN based Simulink model of two area power system

By utilizing the ANN method, we can reduce oscillation and settling time and obtain improved dynamic responses. The reaction of the power system is also influenced by the rated power capacity of any system.

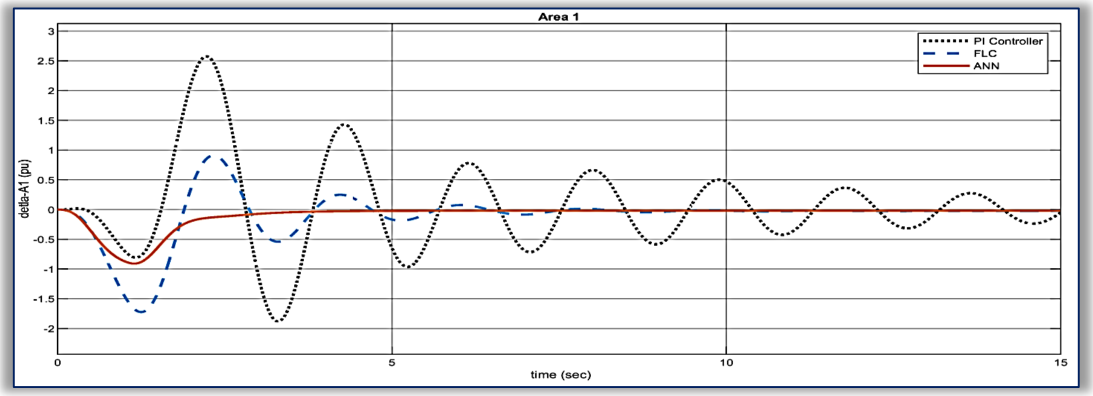

Figure 9: Response using PI, FLC and ANN controller for area 1 of power system.

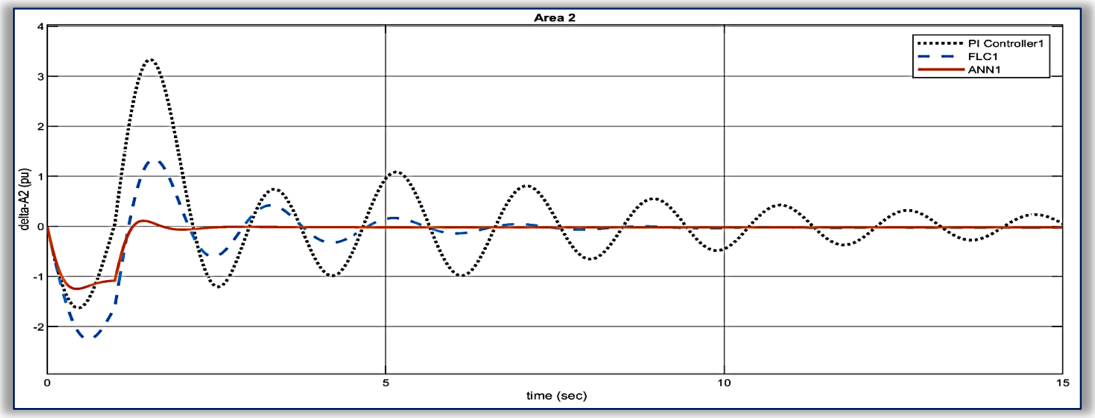

Figure 10: Frequency response for area 2 of power system.

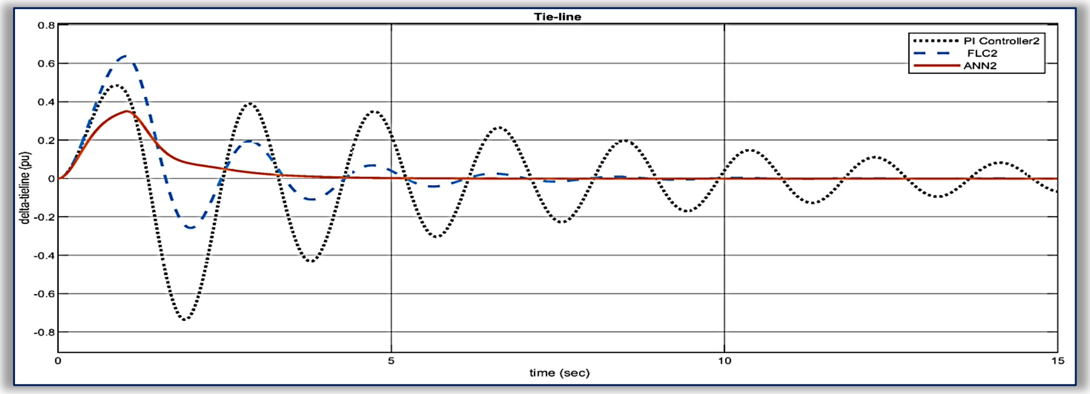

Figure 11: Frequency output response tie-line of power system.

5. RESULTS & DISCUSSION

The output responses illustrates how the suggested ANN controller has over 85% better overshoots than the proposed PI controller and how the conventional PI controller's setting time is significantly longer as shown in Fig. 9, Fig. 10 and Fig.11. This investigation demonstrates that the suggested ANN controller produces better overshoots and settling times than the outputs of the other controllers. The Table 2 summaries the decrease in transient dip frequency as well as the reduction in peak and settling times. We have achieved 10-30% reduction in peak time and 40% reduction in settling time through brain control. Thus, we recommend using the Levenberg-Marquardt approach to supervise the neural controller throughout its online training. We present a more effective neural network trained online using particle swarm optimization for further research.

Table 2: Result comparison of PI, FLC and ANN

Controller	Parameter		
	Overshoot	Oscillations	Settling time (sec.)
PI	Peak	More	35
FLC	Medium	Less	8
ANN	Low	Less	3

6. CONCLUSION

The automatic load frequency regulation of two area power systems has been studied using artificial neural network controllers. In order to achieve this, an ANN controller was initially designed to increase the system's sensitivity. In addition, the system was subjected to a traditional PI, PID and FLC controller for comparison. It has been demonstrated that the suggested control algorithm works well and significantly boosts system performance. For this reason, it is advised to use the suggested ANN controller to provide dependable, high-quality electricity. Additionally, because it doesn't require a lot of knowledge about the system characteristics, the proposed controller is relatively straightforward and quick to implement. It has been successfully accomplished to regulate the turbine reference power of a computer-simulated generator unit using neural networks.

The primary goal of the work was to demonstrate the effectiveness of a neural controller in the field of automatic load frequency regulation that had been trained using the Levenberg-Marquardt method. The outcomes are quite commendable and encourage more work in this specific field.

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