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An artificial neural network approach of load frequency control in a multi area interconnected power system

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ABSTRACT

Variation in load frequency is an index for normal operation of power systems. When load Perturbation takes place anywhere in any area of the system, it will affect the frequency at other areas also. To control load frequency of power systems various controllers are used in different areas, but due to non-linearity's in the system components and alternators, these controllers cannot control the frequency quickly and efficiently. The simple neural networks can alleviate this difficulty. This paper deals with the Artificial Neural Network (ANN) is applied to self tune the parameters of Proportional-Integral-Derivative(PID) ontroller. The single, Two Area non-reheat system has been considered for simulation of the proposed self tuning ANN based PID controller. In the PID controller parameters are continuously adjusted according to the change in area-control error (ACE). Simulations of the networks are carried out for different load changes 1% and change of 1% in governor time constant and turbine time constant parameters. The proposed method for simulation results are obtained by the other controllers of PI and PID compared highlighting the performance of PID-ANN controller. The simulation works developed by MATLAB- SIMULINK Environment. The simulink results are obtained by qualitatively and quantitatively .The qualitative comparison is used for the Integral Square Error (ISE), Integral Absolute Error (IAE) and Integral Time Absolute Error (ITAE) is minimized in single and multi area power system. Therefore the Comparison of responses with conventional integral controller(PI) & PID controller show that the neural-network controller (ANN-PID) has quite satisfactory generalization capability, feasibility and reliability, as well as accuracy in both single and multi area power system.

Introduction

Modern Power Systems, with increasing electrical power demand are becoming more and more complicated. Therefore, it is required to supply the electrical power supply with stability and high reliability. Large interconnected power systems consists of interconnected control areas which are connected through tie lines. Automatic Generation Control (AGC) or Load Frequency Control (LFC) is an important issue in Power System Operation and Control for supplying stable and reliable electric power with good quality. The principle aspect of Automatic Load Frequency Control is to maintain the generator power output and frequency within the prescribed limits. Each control area is responsible for individual load changes and scheduled interchanges with neighboring areas. Area load changes and abnormal conditions leads to mismatches in frequency and tie line power interchanges which are to be maintained in the permissible limits, for the robust operation of the power system. For simplicity, the effects of governor dead band are neglected in the Load Frequency Control studies. To study the realistic analysis of the system performance, the governor dead band effect is to be incorporated.

Load frequency Control (LFC)

The aim of LFC is to maintain real power balance in the system through control of system frequency. When ever the real power demand changes, a frequency change occurs. This frequency error is amplified, mixed and changed to a command signal which is sent to turbine governor. The governor operates to restore the balance between the input and output by changing the turbine output. This method is also referred as Megawatt frequency or Power-frequency (P-f) control.

Problem Definition

In order to keep the power system in normal operating state, a number of controllers are used in practice. As the demand deviates from its normal operating value the system state changes.

Different types of controllers based on classical linear control theory have been developed in the past. Because of the inherent non-linearities in system components and synchronous machines, neural network techniques are considered to build non-linear ANN controller with high degree of performance.

Most load frequency controllers are primarily composed of an integral controller. The integrator gain is set to a level that compromise between fast transient recovery and low overshoot in the dynamic response of the overall system. This type of controller is slow and does not allow the controller designer to take into account possible non-linearities in the generator unit.

Multi Area System Modeling

In multi area system load change in one area will affect the generation in all other interconnected areas. Tie line power flow should also be taken into account other than change in frequency. We will discuss two area and three area systems in the following session.

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Governor Model

Suppose a generating unit is operated with fixed mechanical power output from the turbine. The result of any load change would be a speed change sufficient to cause the frequency-sensitive load to exactly compensate for the load change. This condition would allow system frequency to drift far outside acceptable limits.

This is overcome by adding mechanism that senses the machine speed, and adjusts the input valve to change the mechanical power output to compensate for load changes and to restore frequency to nominal value.

The earliest such mechanism used rotating “fly balls” to sense speed and to provide mechanical motion in response to speed changes.

Modern governors use electronic means to sense speed changes and often use a combination of electronic, mechanic and hydraulic means to effect the required valve position changes.

The simplest governor, called the isochronous governor, adjusts the input valve to a point that brings frequency back to nominal value. If we simply connect the output of the speed-sensing mechanism to the valve through a direct linkage, it would never bring the frequency to nominal.

To force the frequency error to zero, one must provide reset action. Reset action is accomplished by integrating the frequency (or speed) error, which is the difference between actual speed and desired or reference spe. The speed-measurement device’s output, ω, is compared with a reference, ωref , to produce an error signal, Δω.

The error, Δω, is negated and then amplified by a gain KG and integrated to produce a control signal, ΔPvalve , which cause main steam supply valve to (ΔPvalve position) when Δω is negative. If, for example, the machine is running at reference speed and the electrical load increases, ω will fall below ωref and Δω will be negative.

The action of the gain and integrator will be to open the steam valve, causing the turbine to increase its mechanical output, thereby increasing the electrical output of the generator and increasing the speed ω.

When ω exactly equals ωref , the steam valve the new position (further opened) to allow the turbine generator to meet the increased electrical load.

The isochronous (constant speed) governor cannot be used if two or more generators are electrically connected to the same system since each generator would have to have precisely the same speed setting or they would fight each other, each trying to pull the system’s speed (or frequency) to its own setting.

To run two or more generating units in parallel, the speed governors are provided with a feedback signal that causes the speed error to go to zero at different values of generator output.

Two Area System

In two-area system, two single area systems are interconnected via the tie line. Interconnection established increases the overall system reliability.

Even if some generating units in one area fail, the generating units in the other area can compensate to meet the load demand.

A complete block diagram representation of isolated power system comprising turbine, generator, governor and load is obtained by combining the block diagram of individual components. The block diagram with feedback loop is as shown in Fig.1

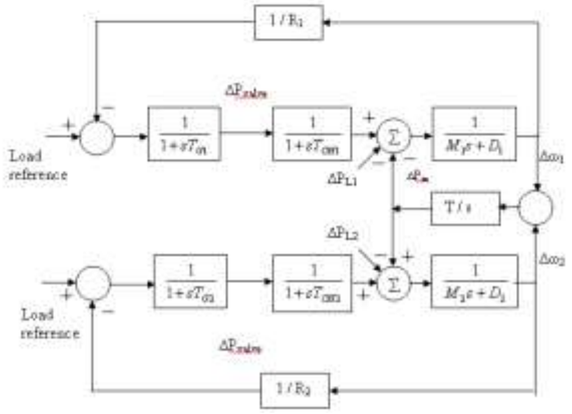


Figure1.. Block diagram of interconnected areas

Tie-Line Control

When two utilities interconnect their systems they do so for several reasons. One is to be able to buy and sell power with neighboring systems whose operating costs make such transactions profitable. Further, even if no power is being transmitted over ties to neighboring systems, if one system has a sudden loss of a generating unit, the units throughout all the interconnection will experience a frequency change and can help in restoring frequency. Interconnections present a very interesting control problem with respect to allocation of generation to meet load.

Tie line control system must use two pieces of information: the system frequency and the net power flowing in or out over the tie lines. Such a control scheme would, of necessity, have to recognize the following.

(i) If frequency decreased and net interchange power leaving the system increased, a load increase has occurred outside the system.

(ii) If frequency decreased and net interchange power leaving the system decreased, a load increase has occurred inside the system.

This can be extended to cases where frequency increases. We will make the following definitions.

$P_{net\ int}$ = total actual net interchange

(+ for power leaving the system; — for power entering)

$P_{net\ int\ sched}$ = scheduled or desired value of interchange

$\Delta P_{net\ int} = P_{net\ int} - P_{net\ int\ sched}$

Summary of the tie line frequency control scheme can be given as in the table 1.1.

$\Delta\omega$	$\Delta P_{net\ int}$	Load change	Resulting control action
-	-	ΔP_{L1} + ΔP_{L2} 0	increase P_{gen} in system 1
+	+	ΔP_{L1} - ΔP_{L2} 0	Decrease P_{gen} in system 1
-	+	ΔP_{L1} 0 ΔP_{L2} +	increase P_{gen} in system 2

Adaptation of Artificial Neural Network

In a system, if inputs and the corresponding targets are identified, then we can implement the Artificial Neural Network (ANN) for the input – target pair. ANN is computationally simple, reliable, model free system. One of the main advantages of ANN is, desired output can be obtained for even untrained data within the input range.

In this paper training is carried out using NNTOOL box in MATLAB software version 6.1. NNTOOL method provides the facility to train through one of the methods Say conjugate gradient method, Levenberg-Marquardt method for back propagation. In this paper Levenberg-Marquardt method is employed for it's superiority in convergence.

In the neural network developed (Figure.2) TANSIG is employed as transfer function in the hidden layer and PURELIN in the output layer. Then the obtained weights and biases are chosen as the initial weights and biases.

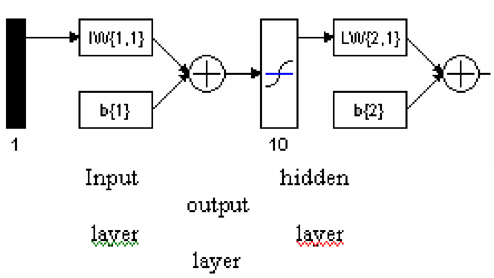


Figure. 2 Neural netwrk for the design of ANN based PID controller

Training Procedure:

Import inputs to the network & corresponding targets either from current workspace or from a file.

Step1: Choose new network icon in the box to create a new neural network.

Step 2: Creation of New Network In this box we can choose the number of layers, number of neurons in each layer and input ranges .

Step 3: Initialization of the network

Step 4: Simulation of the neural network

Step 5: Training the neural network

Step 6: Adaptation of the neural network with trained data

Step 7: Required weights and biases for the neural network

Design of ANN Controller in Tuning PID Controller Parameters

The range over which error signal is in transient state, is observed. Corresponding values of the proportional, integral and derivative constants are set. This set is kept as target. Range of error signal is taken as the input. This input – target pair is fed and new neural network is formed using "nntool" in the MATLAB Simulink software. Updated weights and biases are given to a fresh neural network. Now the neural network is ready for operation.

The error signal is given as input to the neural network using MATLAB function. Desired target for each input value is obtained. The fresh neural network is written as program and is incorporated in the MATLAB function tool, in simulink diagram. Thus for each error signal fed as input, trained PID controller parameters K_P, K_I, K_D are given back as output to called MATLAB function tool in simulink diagram.

As the neural network developed is purely dependant on the area control error signal, the network trained can be used for both single and two area systems. Further as the neural network is independent of the time instant, the trained network is more reliable for all disturbances which may occur at different time instances.

For any load change, the required change in generation, called the area control error or ACE, represents the shift in the areas generation required to restore frequency and net interchange to their desired values. Maximum and minimum values of ACE occur in transient state and steady state respectively.

Simulation studies

This paper deals with the following case studies simulated work developed by MATLAB Environment.

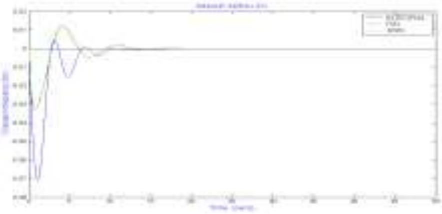
Case 1: Simulation of Single Area power system.

Case 2: Simulation of Single Area power system with 10% Change in governor time parameters.

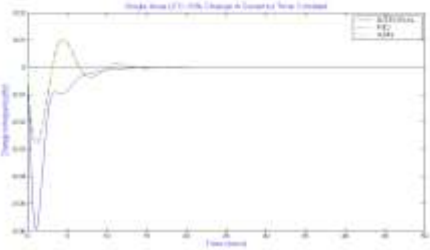
Case 3: Simulation of Single Area power system with 10% Change in turbine time parameters.

Case 4: Simulation of Two area system.

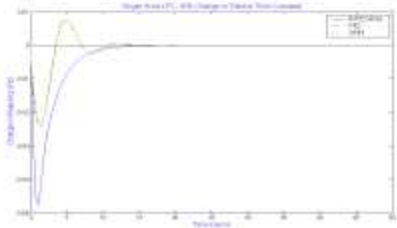
Case 5: Obtained the Area Control Error vale of ISE/IAE/ITAE.



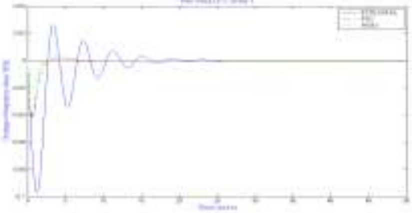
Simulation of Single Area power system



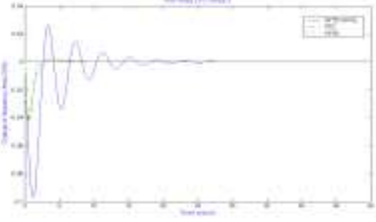
Simulation of Single Area power system with 10% Change in governor time parameters



Simulation of Single Area power system with 10% Change in turbine time parameters



Simulation of Two area system in area 1



Simulation of Two area system in Area 2

With the reference to the results obtained as shown in Table2. we can conclude that the performance indices IAE/ISE/ITAE are minimum both Area 1 and Area 2 .When ANN controller compared to that of Integral and PID controllers.

Conclusion

From the simulation results obtained for load disturbances for ANN controller, PID controller, Conventional integral controller we can conclude that ANN controller is faster than the other, Peak undershoot is reduced, Settling time is reduced. The superiority of ANN controller is established in the cases of two area systems. From the Qualitative and Quantitative comparison of the results we can conclude that the ANN controller yields better results. ANN controller gives minimum IAE/ISE/ITAE compared to the conventional integral and PID controllers.

Quantitative Comparison

PERFORMANCE INDICES			
CHANGE IN FREQUENCY IN Hz	IAE	ISE	ITAE
INTEGRAL			
$\Delta f1$	0.1793	0.0072	0.5572
$\Delta f2$	0.2932	0.0142	1.2304
PID			
$\Delta f1$	0.0443	8.2026e-004	0.0602
$\Delta f2$	0.0513	0.0014	0.0649
ANN			
$\Delta f1$	0.0487	8.0973e-004	0.0799
$\Delta f2$	0.0577	0.0014	0.0885

The simulation studies were also done for change in the operating conditions like change in governor time and turbine time constants. The Qualitative comparisons of all the controllers show that the ANN results in robust performance. Hence ANN controller has large potential to be used as a control strategy for the Load Frequency Control.

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Appendix:

Parameters	**Area 1**	**Area 2**
Turbine time constant	0.5 s	0.6s
Generator Time constant	0.2s	0.3s
Generator Angular Momentum	10 MJrad/s	8 MJrad/s
Governor Speed Regulation	0.05 pu	0.065 pu
Load change for Frequency change of 1% D = $\Delta p / \Delta f$	0.6% 0.6	0.9% 0.9
Rated output	250 MW	250 MW
Sudden Load Variation	250 MW 250/250=1p.u	250 MW 250/250=1p