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NARMA-L2 controller for five-area load frequency control

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Abstract

This paper investigates the load-frequency control (LFC) based on neural network for improving power system dynamic performance. In this paper an Artificial Neural Network (ANN) basedcontroller is presented for the Load Frequency Control (LFC) of a five area interconnected power system. The controller is adaptive and is based on a nonlinear auto regressive moving average (NARMA-L2) algorithm. The working of the conventional controller and ANN based NARMA L2 controllers is simulated using MATLAB/SIMULINK package.. The Simulink link results of both the controllers are compared.

Keywords: Area Control Error (ACE), Artificial Neural Network (ANN), Genetic Algorithm (GA), Load Frequency Control (LFC), Artificial Neural Network (ANN)

The organizations are responsible for providing electrical power with great reliability, availability and efficiency. In present time the demand for electrical power and load is not constant but kept on changing. It becomes necessary to change power generations according to load perturbations. A power system consists of a number of interconnected subsystems. For each subsystem it becomes compulsory to fulfill the requirements usually include matching system generation to system load and the associated system losses and then regulating system frequency and tie line power exchanges. This is usually known as load frequency control, also called Automatic Generation Control (AGC) problem and is very important in the operation of power systems [1, 2]. The main function of AGC is to maintain the real frequency and the desired power output (megawatt) in the interconnected power system and to control the change in tie line power between control areas.

To maintain the system at normal operating state different types of controllers based on classical and modern control theories have been developed [3-5]. The conventional controller used for Load Frequency Control is integral controller. The integrator gain is set to a level such that relation between fast transient recovery and low overshoot in the dynamic response of the overall system can be maintained [6-7]. But the main disadvantage of this type of controller is slow and does not give desired performance to the designer corresponding to non-linarites in the generator unit.

In recent years, modern control techniques, especially adaptive control configurations, are applied to load-frequency control. The applications of artificial neural networks, genetic algorithms, fuzzy logic and optimal control to LFC have been reported in [8-15]. In the paper, artificial neural network (ANN) based controller is used, which is an adaptive control configuration because this controller provides faster and desired control as compared to others. The beginning of artificial intelligence (AI) techniques leads to many problems. This technology mainly used systems which are operating nonlinearly over the operating range. ANN has also been used in frequency controller design for Multi area AGC scheme in deregulated electricity market**.** These networks are also applicable for pattern recognition, function approximation, time series prediction and classification problems for quite some time. .

Nonlinear autoregressive moving average (NARMA) model is an exact representation of input-output behavior of a finite-dimensional and nonlinear discrete time dynamic plant in neighborhood of the equilibrium state [16,17]. This non-linearity, its implementation for real time control systems makes difficult. To overcome computational complexity related to use of this type of ANN, two classes of NARMA are introduced in [16]: NARMA-L1 and NARMA-L2. The latter is more convenient to be practically implemented using multilayer neural networks.

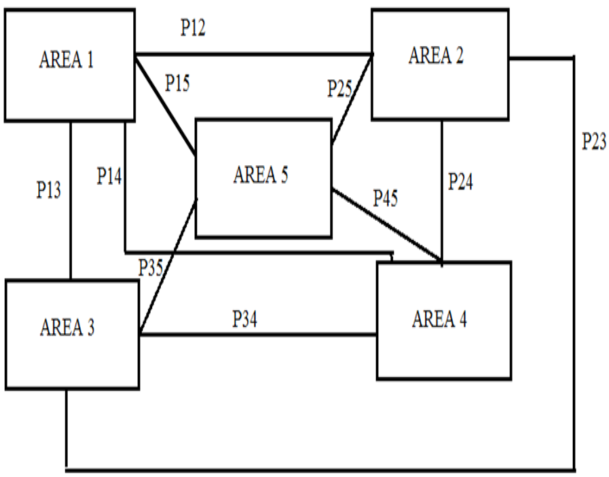

Figure 1: Basic Block Diagram of Five area interconnected system

FIVE-area Load-Frequency Control Model

The configuration of the investigated power system is given in Figure 1. The directions of power transfer between areas have been considered as follow:

- from area 1 to area 2 - from area 1 to area 3
- from area 1 to area 4 - from area 1 to area 5
- from area 2 to area 3 - from area 2 to area 4
- from area 2 to area 5 -from area 3 to area 4
- from area 3 to area 5 - from area 4 to area 5

A five area interconnected power system [18] is selected and load frequency control of this system is made primarily by integral controller and then by an ANN controller [19], [20], [21]. The five areas are interconnected to each other by tie-lines. It is seen that each area needs its system frequency to be controlled [22], [23], [24] to give desired performance. The reason for using the proposed controller is due to the fact that it firstly adapts to changing operating points and calculates optimal control commands, it can also perform effectively with nonlinearities and even if system inputs are temporarily lost or errors are introduced. The maincharacteristics of ANN controller is that it continues to function without needing any decision support software in case of a failure. For comparison, the AGC of considered power system is accomplished using:

(i) Conventional Integral controller

(ii) ANN based NARMA L2 Controller

Modelling and simulation withconventional integral controller

In five area system, five single area systems are interconnected via tie-line. The interconnection of power systems increases the overall system reliability. In this case if some generating units in one area fail, the generating units in the other area can compensate to meet the load demand. The basic block diagram of five area interconnected power system is shown in Fig.1.

The power transfer through tie line for the model is given by:

$$P_{tie,\,1} = \frac{|V_1||V_2|}{X_{12}} \sin(\delta^0{}_1 - \delta^0{}_2)$$

$\delta°_1$, $\delta°_2$ = power angles (angle between rotating magnetic flux and rotor) of equivalent machines of the two areas

$\Delta P_{tie,\,1}(pu) = T_{12}\,(\Delta\delta_1 - \Delta\delta_2)$

Where

$$T_{12} = \frac{|V_1||V_2|}{P_{r1}X_{12}} \cos(\delta^0{}_1 - \delta^0{}_2)$$ = synchronizing coefficient

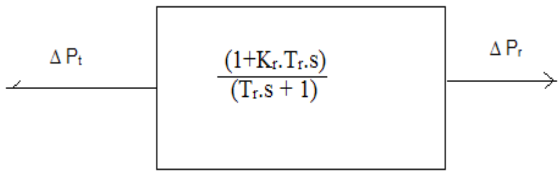

Figure 2: Turbine model

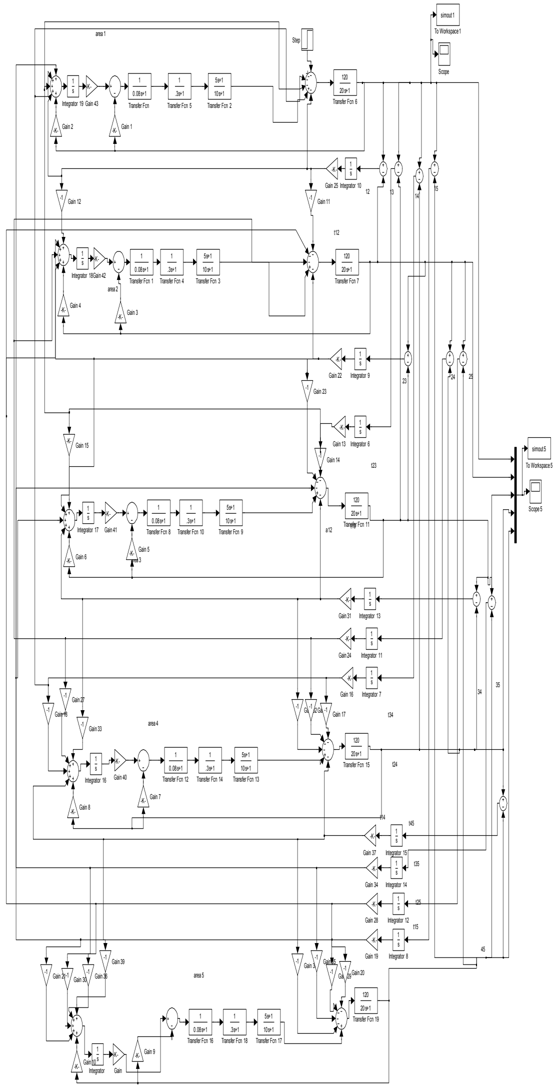

Figure 3. Simulink Model for Five Area LFC with Reheat turbine

A conventional integral controller is used on five area power system model. The integral controller improves steady state error and allows a transient response with little or no overshoot. As long as error remains, the integral output will increase and the speed changer position attains a constant value only when the frequency error has reduced to zero. The SIMULINK model of a five area interconnected power system with reheat turbine using integral controller is shown in Figure 3.

Artificial neural network

ANN as the name suggests is information processing system. In this system the element used for processing the information is called as neurons. The connecting links used for transmitting signals process an associated weight, which is multiplied along with the incoming signal (net input) for any typical neural net. The output signal is obtained by applying activation function to the net input. Neural network architecture-the multilayer perceptron as unknown function are shown in Fig 4. Parameters of the network are adjusted so that it produces the same response as the unknown function, if the same input is applied to both systems. The unknown function could also represent the inverse of a system being controlled; in this case the neural network can be used to implement the controller [25].

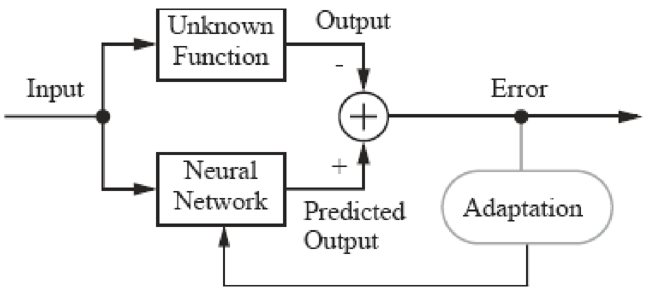

Figure 4: Neural Network as Function Approximator

The basis features of neural networks are high computational rates, fault tolerance, self-decision capability, learning or training, goal –seeking, adaptive features, primitive computational elements

NARMA-L2 Control

ANN controller architecture employed here is Nonlinear Auto Regressive Moving Average (NARMA) model is representation of input output behavior of a finite-dimensional and nonlinear discrete time dynamic plant in neighborhood of the equilibrium state [27-29]. The non-linearity property of the ANN controllermakes its implementation for real time control systems difficult. To overcome computational complexity of ANN controllers, two classes of NARMA are introduced in [27]: NARMA-L1 and NARMA-L2. The NARMAL2 is more convenient to practically implemented using multi-layer neural networks.

This controller is simply a rearrangement of the neural network plant model, which is trained

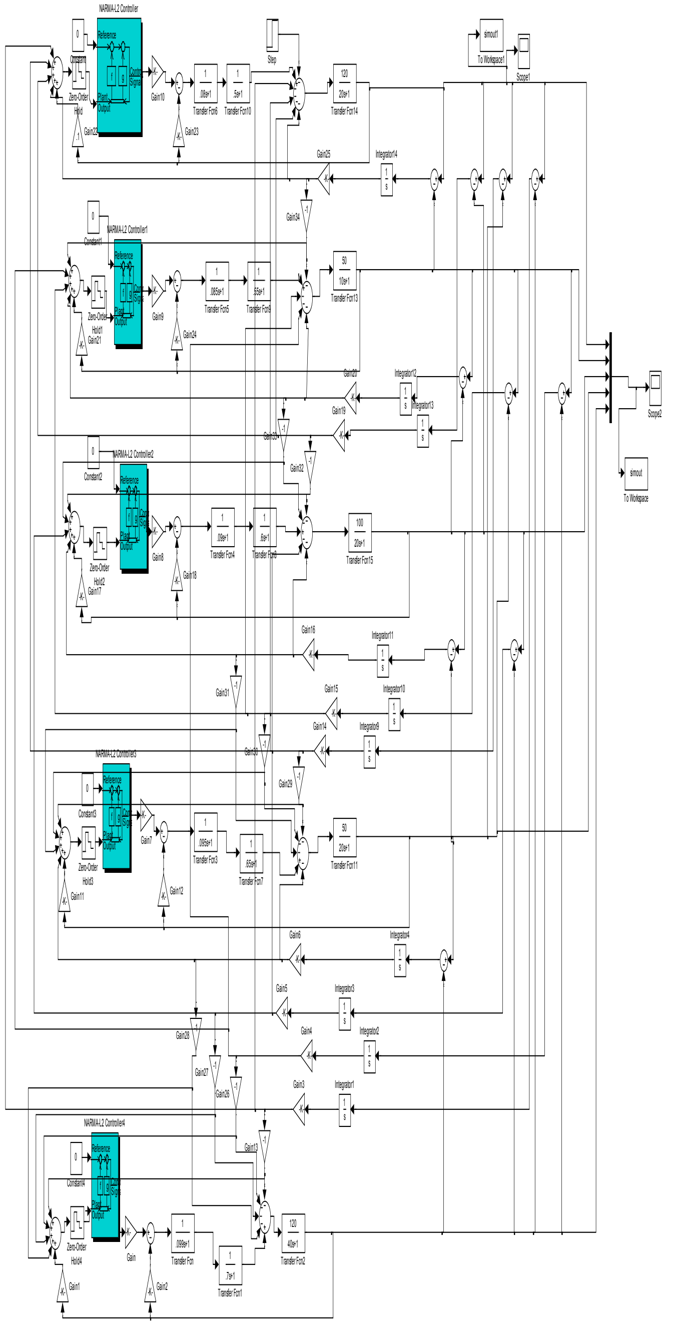

Figure 6. Simulink Model for Five Area LFC using Narma L2

offline, in batch form. NARMA L2 controller mainly consists ofreference, plant output and control signal.Computation required for this type of controller is very less. The plant output is forced to track the reference model output and the effect of controller changes on plant output is predicted for further calculations. The main quality of this controller is that permits the updating of controller parameters.

In this controller, the frequency deviations, tie-line power deviation and load perturbation of the area are chosen as the neural network controller inputs. Control signals applied to the governors in the area act as the outputs of the neural network. The data required for the ANN controller training is obtained by designing the Reference Model Neural Network and applying to the power system with step response load disturbance. NARMA-L2 is one of the important neural network architecture that has been implemented in the MATLAB for prediction and control of various systems. NARMA-L2 controller design is performed by two stages i.e. System identification and Control design

The outputs of the neural network are the control signals, which are applied to the speed governors in the corresponding area. After a series of trial and error and modifications, the ANN architecture which provides the best performance is selected. In this case it is a three-layer perceptron with five inputs, 13 neurons in the hidden layer, and one output in the ANN controller that is selected. The activation function of the networks neurons is trainlm function.300 training sample has been taken to train 300 no of epochs. The proposed network has been trained by using the learning performance.

Simulation results and comparative analysis

Simulation studies have been performed on five-area power system that was explained in section 2 along with the block diagram is simulated using MATLAB/Simulink. Typical data for system parameters have been given in appendix A. The main objectives of proposed controller are regulation of the terminal frequency near to the nominal value at the area output and minimizing the deviation between the actual and reference ACE values.The

simulation results with conventional controller are shown in Figure 7 and with ANN controller is shown in Fig.8. The test system for AGC as shown in Figure 2 consists of five control areas and the parameters are given in the Appendix-B. The considered system is controlled using conventional Integral controller and ANN controller separately with 1% Step load perturbation is given in area-1. The simulations results show that the dynamic responses obtained using ANN controller satisfy the AGC requirements better than conventional controller. It is evident that all area frequency deviations settle very fast with zero steady state error. The dynamic response using ANN controller and Integral controller is shown in Figure 9. This shows that the settling time and undershoots are improved significantly with ANN controller.

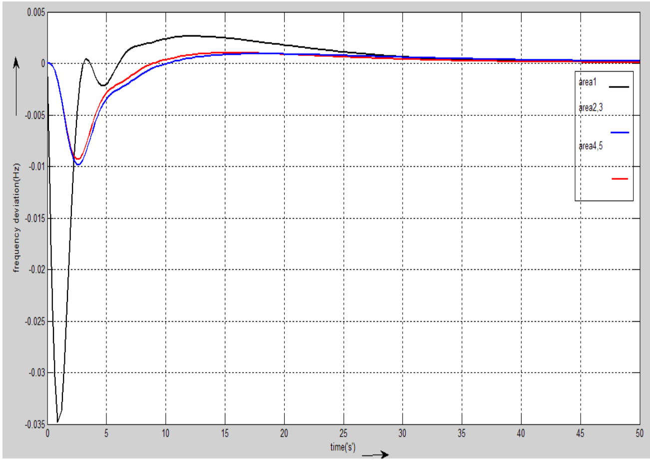

Fig.7 SIMULINK Model Results for Five Area LFC using conventional controller

Finally, the comparison is made between the performance characteristics of Load Frequency Control(LFC) using the integral controller and ANN based NARMA L2 controller. It is found that the later controller is more efficient for the desired performance and it is preferably used.

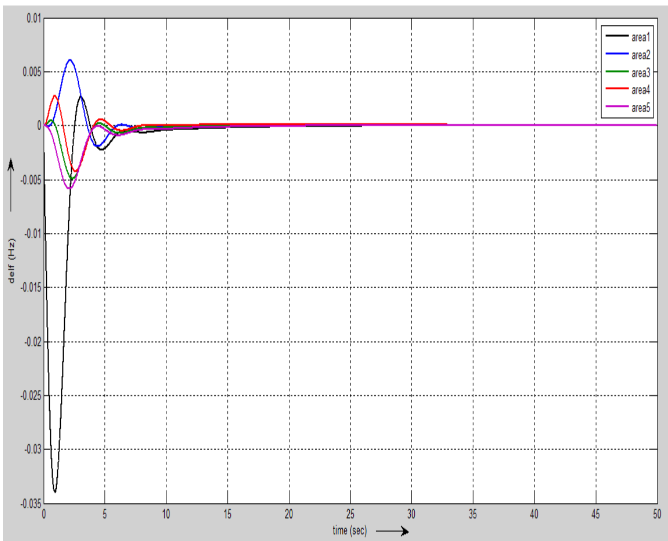

Figure 8. Response of Five Area LFC considering Reheat turbine With ANN

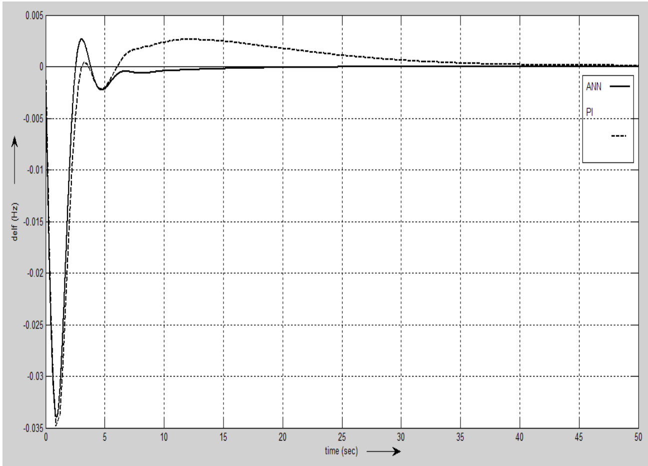

Figure 9. Comparison of response of ANN with integral controller for five area for area 1 for 1% disturbance in load of area 1

Conclusion

In this paper, an ANN based controller for load frequency control (LFC) of a five-area interconnected power system was used. The NARMA-L2 controller was compared with an integral controller.The results obtained from the simulation show that NARMA-L2 controller gives good transient response and it is robust to variations in system parameter changes

APPENDIX-A

Nomenclature

ΔF1, ΔF2, ΔF3, ΔF4, ΔF5 = change in frequencyΔPe = load incrementR= speed regulationKg1,Kg2,Kg3,Kg4,Kg5 = gain of speed governorTg1,Tg2,Tg3,Tg4,Tg5 = time constant of governorKt1,Kt2,Kt3,Kt4,Kt5 = gain of turbineTt1,Tt2,Tt3,Tt4,Tt5 = time constant of turbineKr1,Kr2,Kr3,Kr4,Kr5 = gain of reheat turbineTr,Tr1,Tr2,Tr3,Tr4,Tr5 = time constant of reheat turbineKps1,Kps2,Kps3,Kps4,Kps5 = gain of generatorTps1,Tps2,Tps3,Tps4,Tps5 = time constant of generatorTs = sampling time ΔPg1, ΔPg2, ΔPg3, ΔPg4, ΔPg5= governor output ΔPt1, ΔPt2, ΔPt3, ΔPt4, ΔPt5 = turbine outputΔPr1, ΔPr2, ΔPr3, ΔPr4, ΔPr5 = reheat turbine ou tputP12,P13,P14,P15,P23,P24,P25,P34,P35,P45 = tie linepowerT12,T13,T14,T15,T23,T24,T25,T3 4,T35,T45 = tie line timeconstantKi = integral controller gainb1,b2,b3,b4,b5 = bias factor

APPENDIX-B

Nominal parameters of the system investigatedF=50Hz, Tg1=Tg2=Tg3=Tg4=Tg5=0.08s,Tr1=T r2=Tr3=Tr4=Tr5=10 s,H1=H2 =H3=H4=H5=5,Tt1=Tt2=Tt3=Tt4=Tt5=0.3sKr1=Kr2=Kr3=Kr4=Kr5= 0.5Hz/puMW,Ptiemax=200MW, Tps1=Tps2=Tps3=Tps4=Tps5=20s,Kps1=Kps2=Kps3=Kps4=Kp s5=120Hz/p.uMW;T12=0.08674; Ki=0.1,Ts=0.01,

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