Load Frequency Control of Multi Area Power System for EV charging using ANFIS controller

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Abstract

Load Frequency Control (LFC) is used to regulate and control the output frequency signal of the electric generated power within an area in response to changes in system loads. The gain constants in the case of conventional controllers remain the same throughout, for changes in the load value. However, Load cannot be the same throughout, load deviates from time to time. To get rid of these disadvantages related to conventional controllers, a lot many schemes have been put forth in the literature. This work presents a new design of various types of load frequency controllers based on different types of Artificial Intelligent (AI) optimization techniques such as Fuzzy logic, ANN tuner for a two-area power system. The performance of the controller understudy shows an enhancement in the frequency deviation signal as well as the peak overshoot and settling time for the frequency output signal. The performance of the proposed scheme is validated using MATLAB/ SIMULINK tools.

Keywords— ***LFC, ANN, ANFIS, PI, Fuzzy, Multi-Area Power System.***

Introduction

As the loading in a power system is not constant so the controllers for the system must be aimed to provide quality service in the power system. The power flow and frequency in an interconnected system are well regulated by AGC. The main purpose of the AGC is to retain the system frequency constant and almost inert to any disturbances. Generally, two things are being controlled in AGC i.e. voltage and frequency. Both have separate control loops and independent of each other.

Apart from controlling the frequency, the secondary majors are to maintain a zero steady-state error and to ensure optimal transient behavior within the interconnected Areas. The objective is to design a controller to apprehend preferred power flow and frequency in a two Area power system.

The input mechanical power is utilized to control the frequency of the generators and the variation in the frequency and tie-line power are detected, which is the extent of the alteration in the rotor angle. A decently outlined power framework ought to have the capacity to give satisfactory levels of power quality by keeping the frequency and voltage size inside the middle of as far as possible.

I. LITERATURE REVIEW

[1] The Grids face a new and important challenge: the oncoming mass penetration of plug-in Electrical Vehicles (EVs). Nevertheless, the architectures of transmission and distribution grids are still focused on traditional design and operational rules. Consequently, it is necessary to predict the adequate solutions for the problems which are going to rise to the electrical and production grids as well as the effect on their commercial operation as a result of the gradual integration of EVs into the network. [2] In renewable penetrated power systems, frequency instability arises due to the volatile nature of renewable energy sources (RES) and load disturbances. The traditional load frequency control (LFC) strategy from conventional power sources (CPS) alone unable to control the frequency deviations caused by the aforementioned disturbances. Therefore, it is essential to modify the structure of LFC, to handle the disturbances caused by the RES and load. [3] The rapid development of technology used in electric vehicles, and in particular their penetration in electricity networks, is a major challenge for the area of electric power systems.

The utilization of the battery capacity of the interconnected vehicles can bring significant benefits to the network via the Vehicle to Grid (V2G) operation. [4] The use of the proportional-integral (PI) algorithm incorporated with the fuzzy logic technique has been proposed as an advanced gain scheduling load frequency control (GLFC) in two-area power systems. The proposed controller comprises two-level control systems, such that it consists of a pure integral compensator, which is connected, in parallel with a PI controller. However, and based on load demand, the PI parameters are updated online by means of fuzzy logic rules. With this control technique, it becomes possible to eliminate steady-state errors as well as to maintain good transient responses. The task of keeping a stable and overall satisfactory mode of operation in interconnected electric power systems is the main goal of any control strategy. [5] This study aims to develop a Load Frequency Control (LFC) for a two-area power system using a fuzzy logic tuned PI controller.

A deviation of frequency value from the standard (±0.5Hz) arises when real power generation fails to supply-demand along with network losses. Various LFC studies have been done exploiting control strategies ranging from classical control schemes to soft analysis techniques. [6]**T**he Artificial Neural Network (ANN) Controller for load frequency control of the Multi-area power system is presented.

The performances of ANN Controller and conventional PI controllers are compared for Two area and Multi-area power systems with non-reheat turbines. [7]**T**he ANN-based proportional-integral-derivative (PID) controller is developed here to maintain the system frequency at the nominal value. Due to some complications of the modern industrial system, the conventional PID controller is not capable to meet our requirements.

The neural network has great capability in solving complex, nonlinear mathematical problems. This paper introduces the design of the neuro-PID controller model to improve the response and performance of the conventional PID controller. [8] A hybrid combination of Neuro and Fuzzy is proposed as a controller to solve the Automatic Generation Control (AGC) problem in a restructured power system that operates under deregulation pedestal on the bilateral policy. In each control area, the effects of the possible contracts are treated as a set of the new input signal in a modified traditional dynamical model.

The prominent advantage of this strategy is its high insensitivity to large load changes and disturbances in the presence of plant parameter discrepancy and system nonlinearities. [9] TheLoad frequency control (LFC) is required for the reliable operation of a large interconnected power system. The main work of load frequency control is to regulate the power output of the generator within a specified area with respect to change in the system frequency and tie-line power; such as to maintain the scheduled system frequency and power interchange with other areas in a prescribe limits. In this paper, the study of the LFC system for a two area. [10] The number of internal combustion vehicles is stagnating, and is even expected to decrease in a few decades, the number of electric vehicles is predicted to increase. Most of the electric cars are designed for daily urban use, thus in the near future, bigger cities might have some ten percentage of electric cars running on their streets during the day.

II. LOAD FREQUENCY CONTROL

With many loads linked to a system in a power system, speed and frequency vary with the characteristics of the governor with variations in loads. No need to modify the setting of the generator if maintaining of constant frequency is not needed. When the constant frequency is needed the turbine speed can be adjusted by varying the governor characteristic.

Let both generating stations are interconnected through a tie line. If the load varies at X or Y & A generation has to maintain the constant frequency, at that time it is known as Flat Frequency Regulation.

- Secondly, where both X & Y have to maintain constant frequency. It is known as parallel frequency regulation.
- Thirdly where frequency maintenance is done of a certain Area by its own generator & keeping constant the tie-line loading. It is called flat tie-line loading control.
- In Selective Frequency control, individually system handles the variation in load itself & without interfering, beyond its limits, the maintenance of the other one in that group.

In Tie-line Load-bias, control all systems in the interconnection help in maintaining frequency no matter where the variation is created. It has a principal load frequency controller & a tie line plotter determining input power on the tie for proper control of frequency.

III. METHODOLOGY

A. ANN

The machine learning technique is not new to the field of science and technology. It has been utilized by various fields to solve complex algorithmic problems. With its excellent development, it has found its way in the field of electrical engineering also. It has been widely used for load forecasting, stability analysis, in solving economic load dispatch, etc. to name a few of them. Due to its strong learning ability, expert systems are easily overtaking digital techniques. Techniques like ANN, ANFIS, etc, which are different forms of machine learning, prove to be very reliable along with providing fast results.

The ANN has advanced methods such as optimal control adaptive control, multivariable control, and different approaches such as microprocessor-based controllers and digital signal processing have been investigated or under investigation.

B. ANFIS

ANFIS stands for Adaptive Neuro-Fuzzy Inference System. The ANFIS controller combines the advantages of a fuzzy controller as well as the quick response and adaptability nature of ANN Fundamentally, ANFIS is about taking a fuzzy inference system (FIS) and tuning it with a backpropagation algorithm based on some collection of input-output data. This allows your fuzzy systems to learn. A network structure facilitates the computation of the gradient vector for parameters in a fuzzy inference system. Once the gradient vector is obtained, a number of optimization routines are applied to reduce an error measure (usually defined by the sum of the squared difference between actual and desired outputs). This process is called learning by example in the neural network literature.

- Some Constraints are as follows: -

Since ANFIS is much more complex than the fuzzy inference systems discussed so far, all the available fuzzy inference system options cannot be used. Specifically, ANFIS only supports Sugeno systems subject to the following constraints:

- First, order Sugeno-type systems.
- The single output is derived by weighted average defuzzification.
- Unity weight for each rule.

An error occurs if your FIS matrix for ANFIS learning does not comply with these constraints. Moreover, ANFIS is highly specialized for speed and cannot accept all the customization options that basic fuzzy inference allows, that is, one cannot make its own membership functions and defuzzification functions; that to make do with the ones provided.

The fuzzy inference system that has been considered is a model that maps:

- – Input characteristics to input membership functions,
- – Input membership function to rules,
- – Rules to a set of output characteristics,
- – Output characteristics to output membership functions, and
- – The output membership function to a single-valued output, or
- – A decision associated with the output.

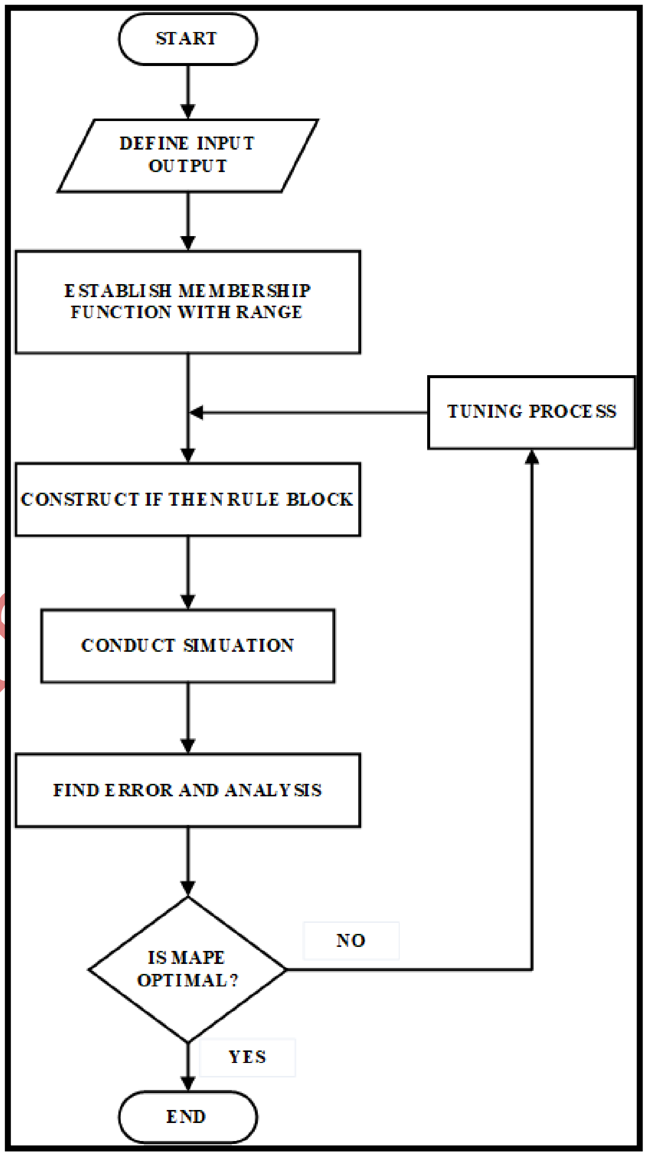

Fig 1 Flow chart for the fuzzy logic model.

The inputs are ACE and Change in ACE. We have studied above the Fuzzy rule base and formed the rules. Two linguistic variables of the inputs and 2 linguistic variables of the output using the NeuroFuzzyAnalyzer toolbox. The membership functions used are

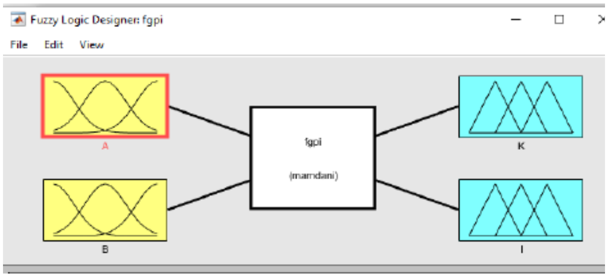

Fig 2 Fuzzy Logic Designer

IV. RESULT

In this section ANN, based PI tuner controller results are discussed. Below figure 2 shows the Simulink model for it. The ANN model is trained and tested with a neural network toolbox in MATLAB only. The model is prepared with data collected from the PID model simulation. Input data consist of ACE and change in ACE and output data consist of Proportional gain and integral gain value. 85% of data is used for training 5% for validation and 10% for testing. The overall regression has a value of more than 0.9 which is considered as good value for any training. Post-development of the model in the neural network toolbox, its Simulink model is prepared from the same GUI.

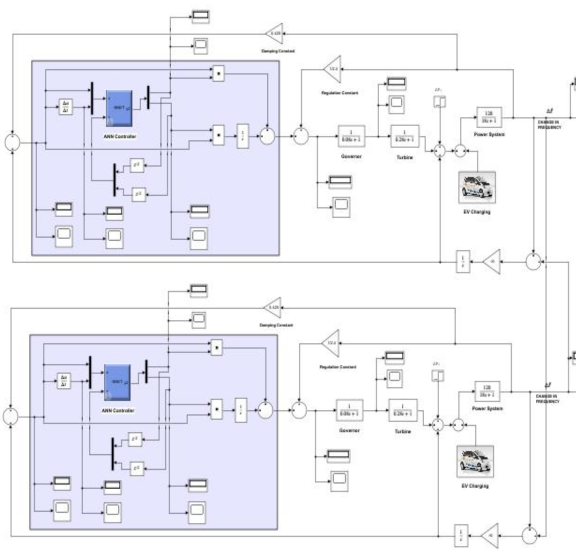

Fig 2 Simulink model of LFC using ANN-PI controller

The above fig2 shows the Simulink model for load frequency control using the ANN-PI controller.

Figure 3 displays the output signal of the Change in the frequency response of DC motor using the ANN-PI controller.

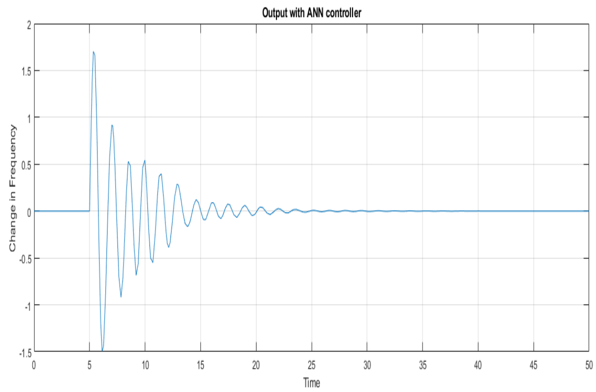

Fig 3 Change in frequency *(Δf)* response for ANN-PI controller.

The below figure 4 shows the Simulink model for load frequency control using the ANFIS controller. The output signal from the controller block after subtracting from the frequency regulator value is supplied to Governor Block. The output from this block is then provided to the turbine block. The output of this block, after subtracting the change in power value is supplied to the power system block to regulate output power so that frequency is maintained at a constant value.

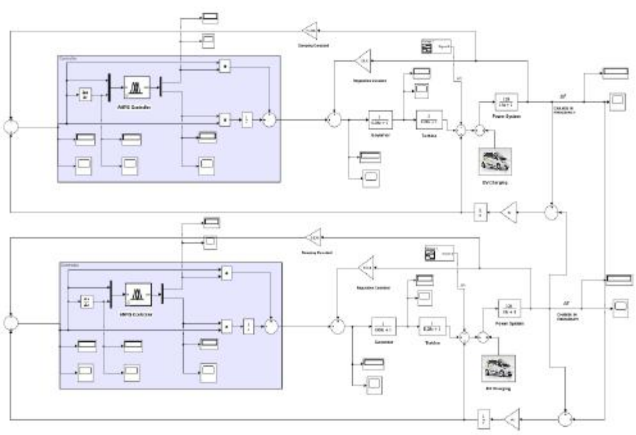

Fig 4 Simulink model of LFC using ANFIS controller

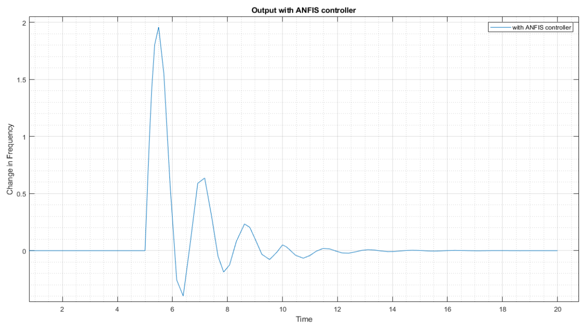

Fig 5 Change in frequency *(Δf)* response for ANFIS controller.

Figure 5 displays the output signal of Change in frequency response using the ANFIS controller.

Table 1 shows the value of LFC response parameters for ANN and ANFIS controller. Based on these parameters the comparison between two controllers will be done to check their performance

TABLE 1:
LFC response parameters

Parameters	***ANN***	***ANFIS***
Rise Time (Sec):	2.2574e-06	1.3832e-05
Settling Time (Sec):	10.2888	11.0145
Settling Min (Hz):	-1.4936	-0.3966
Settling Max (Hz):	0.9185	0.6361
Overshoot:	4.2763e+06	6.6417e+05
Undershoot:	4.8756e+06	3.2790e+06
Peak (Hz):	1.7029	1.9579
Peak Time (Sec):	5.3402	5.4959

V. CONCLUSION

In this work, a two-area power system is designed and simulated successfully. Work of different authors in the field of LFC is discussed in second chapter based on which two technologies are proposed. They are ANN and ANFIS. The effect of load on frequency of generator is noted and controllers are designed accordingly. This work also discusses the consequence of electric vehicles on the load frequency deviation.

Three Matlab/Simulink models are designed using three proposed controllers and are tested and validated. On comparison, it is found that ANN-PI has minimum settling time, whereas ANFIS has a minimum percentage overshoot out of the three. The simulation results in proof that the new techniques are succeeded to improve the controller performance.

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