Comparisons of various controllers in Load Frequency Control of Power Grid with Multi Source Power Generation

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ABSTRACT: Load frequency control is a virtual challenging problem in a realistic complex power system network. Power demand on the grid is unpredictably varying in nature and consequently grid frequency also varies. To alleviate frequency fluctuations on the grid, the renewable energy resources are interfaced with the grid. Renewable resources are abundant and eco-friendly, but the power generation from these sources is intermittent in nature. To provide major contribution of power generation from the renewable energy resources and to reduce cost of unit power generation in control areas, an effective controller is required. Application of an advanced intelligent controller (FUZZY, ANFIS) improve the performance of load frequency control by reducing the frequency deviations. The steady state error and settling time shows the satisfactory performance of the prescribed controller.

INTRODUCTION:

The successful operation of interconnected power systems requires the matching of total generation with total load demand and associated system losses. With time, the operating point of a power system changes, and hence systems may experience deviations in nominal system frequency and scheduled power exchanges to other area, which may yield undesirable effects. To maintain load frequency with in the desirable limits various controlling strategies like classical methods, adaptive and variable structure methods, robust control approaches, intelligent techniques and digital control schemes are available. Various factors affect the system frequency like generation rate constraints, speed governing techniques, load disturbances [1-2]. Load frequency control is a wide problem so, to provide better controlling aspects the system fragmented as a control areas. The control areas have group of generating stations or generating units. In such a control area the power generating plants are alike or different. Generally same plants are grouped for easy controlling. Different plants can be grouped in a single area. The control area maintain the frequency with in the permissible limits by generating required amount of power to meet power demand at every instant of time. The control areas are inter connected with the tie-lines. To exchange power from one area to another area, to operate generating stations most economical manner, to enhance power system stability. The power exchange between controlling areas are based on their contracts and other power generation constraints [3-5].

Control area having different power generating sources like thermal, hydro, diesel, gas, and nuclear plants [6-7]. Generally thermal plants are operated as base load plants. These plants continuously running irrespective of load demand. Due to some faults in the power system the frequency vary larger otherwise the frequency variations with in the acceptable limits [8]. The hydro plants are operated as both peak and base load plants depending upon water availability, plant capacity and load demand [9]. Gas and diesel plants are operated as peak load plants. The integration of these plants with grid is complex due to different factors affect the individual plant performances. The frequency controlling also complex. For short span of load disturbances the energy storage systems are helpful to meet the power demand. The energy systems like SMES, BES, CES, and RFB have been used in load frequency control systems [6]. In conventional methods PI controller is used to limit the area control error and to improve the dynamic performance of the system. The FGP (fuzzy gain PI) controller is widely used to enhance dynamic performance [10]. The new trend concentrating on renewable power generation and integration of grid with this renewable plants. As intermittency of renewable sources makes frequency and voltage control more difficult, short and long term storage plants for electric energy must be relied on to compensate. Due to intermittent nature of power generation, the inter connection of grid with this plants become difficult. For the short distances the renewable generation is most economical. The areas consisting wind power plant, short term storage plant associated with wind power plant, natural fired gas plant, long term storage plant, photovoltaic plant, short term storage plant associated with PV plant [11].

By recent technologies like artificial intelligence techniques and advanced algorithms the integration of grid process become easier. Neural networks, fuzzy inference systems, ANFIS models [12], particle swarm optimization algorithms [13-14], Optimal control methods are used to design the output feedback controller. The optimal feedback controller is applied to two area, optimal quadratic regulators [15-16], optimal feedback controllers [6] are used to control the grid frequency. Distributed generations DG’s are coming into operation to share the load demand. Renewable sources are grouped under DG’s category. Wind power generation most rapidly growing in throughout the world [17-18]. In interconnected systems
the fluctuations in the frequency and voltage leads to outages of lines and generators tend to cascade tripping of lines [19].

The operating point and system parameters are dynamically vary with the frequency. The FUZZY, ANN and ANFIS have best tracking ability of system parameters to optimize frequency fluctuations [20]. The ANFIS controller having self-tuning capability of system parameters and possess advantages of ANN and fuzzy. The fuzzy theory useful to represent the system behaviour with simple linguistic rules, the neural network optimize the parameters [21-22].

Figure 1: Transfer function model of multi-source two area system
ARTIFICIAL INTELLIGENT CONTROLLERS:

FUZZY, ANFIS, Online fuzzy gain tuner controllers extensively using in all fields to resolve the realistic complex problems. The controllers having this future simple realistic rules perform better control action than PI and PID controllers.

Fuzzy derived from fundamental classical set theory. The fuzzy controller mainly have fuzzification block, fuzzy rule base, defuzzification block. The crisp signals are converted into fuzzy membership functions by the fuzzification process. Membership functions are performed based on the fuzzy rule base and produce fuzzified values to the defuzzification block. This block converts fuzzified values into crisp values by the defuzzification process. This is the controller output which is given to the plant to perform the control action.

FUZZY CONTROLLER:

Fuzzy controller have two inputs and single output. The inputs are area controller error (ACE) and change in area control error (ΔACE). Each input having 7 trapezoidal membership functions are NB (Negative Big), NM (Negative Medium), NS (Negative Small), Z (Zero), PS (Positive Small), PM (Positive Medium), PB (Positive Big). The sugeno rule base adopted here and the defuzzification process is centroid method. The fuzzy rules are shown below.

<table>
<thead>
<tr>
<th>$\frac{E}{\Delta E}$</th>
<th>NB</th>
<th>NM</th>
<th>NS</th>
<th>Z</th>
<th>PS</th>
<th>PM</th>
<th>PB</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB</td>
<td>NB</td>
<td>NM</td>
<td>NB</td>
<td>NB</td>
<td>NS</td>
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<td>PM</td>
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<td>NM</td>
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</tbody>
</table>

Table: 1 Fuzzy Rule Base

ANFIS CONTROLLER:

Adaptive neuro fuzzy system controller having features of both neural networks and fuzzy inference systems. The controller having unique feature is that controller can generate the FIS file according to our requirement. This will provide finite optimum tracking operating point to the system. The controller has two inputs area control error (ACE) and change in area control error (ΔACE). Each input having 11 trapezoidal membership functions and 112 output membership functions.

ANFIS controller FIS structure is designed based on the values of area control error (ACE) and change in area control error (ΔACE) at different loading conditions. 11 trapezoidal membership functions are chosen for each input. The training data given to controller and trained then it generate the sugeno rule base with optimum output range. The rules are framed according to our training data. Figure 2 reveals the Anfis rules.

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![Figure 2: Anfis Rule Base Structure](image-url)
**SIMULATION AND RESULTS:**

**Figure 3:** Change in frequency in area 1 with ANFIS controller 20%, 30% loading.

**Figure 4:** Change in frequency in area 2 with ANFIS controller 20%, 30% loading.

**Figure 5:** Change in tie line power with ANFIS controller 20%, 30% loading.

**Figure 6:** Change in frequency in area 1 with FUZZY controller 20%, 30% loading.

**Figure 7:** Change in frequency in area 2 with FUZZY controller 20%, 30% loading.

**Figure 8:** Change in tie line power with FUZZY controller 20%, 30% loading.

Figures 3, 4&5 gives information the control areas 1 & 2 are loaded at 20%, 30% respectively. The frequency changes in respective areas, change in tie line power is shown. ANFIS controller give lesser settling time.

Figures 6, 7&8 gives information the control areas 1 & 2 are loaded at 20%, 30% respectively. The frequency changes in respective areas, change in tie line power is shown. FUZZY controller give satisfactory settling time.
Table: 2 Area1 Frequency Deviation

<table>
<thead>
<tr>
<th>Controller</th>
<th>Rise Time (Sec)</th>
<th>Peak Time (Sec)</th>
<th>Settling Time (Sec)</th>
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<tbody>
<tr>
<td>FUZZY</td>
<td>0.0063</td>
<td>0.2555</td>
<td>15.9973</td>
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<td>ANFIS</td>
<td>0.0025</td>
<td>0.2579</td>
<td>11.3699</td>
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Table: 3 Area2 Frequency Deviation

<table>
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<tr>
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<th>Rise Time (Sec)</th>
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<th>Settling Time (Sec)</th>
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<tbody>
<tr>
<td>FUZZY</td>
<td>0.0064</td>
<td>0.3509</td>
<td>16.1381</td>
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<tr>
<td>ANFIS</td>
<td>0.0025</td>
<td>0.3619</td>
<td>10.5533</td>
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</table>

Table: 4 Tie Line Power Deviation

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<th>Rise Time (Sec)</th>
<th>Peak Time (Sec)</th>
<th>Settling Time (Sec)</th>
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</thead>
<tbody>
<tr>
<td>FUZZY</td>
<td>2.25e-04</td>
<td>0.3125</td>
<td>13.524</td>
</tr>
<tr>
<td>ANFIS</td>
<td>2.252e-04</td>
<td>0.3099</td>
<td>6.7179</td>
</tr>
</tbody>
</table>

Tables 2, 3 & 4 shows comparison of control area1 frequency, control area2 frequency and tie line power with fuzzy and Anfis controller at 20%, 30% loading on the respective control areas. The Anfis controller reduce the settling time compare to Fuzzy controller. This reveals finite settling of frequencies with zero steady state error. Comparison:

Comparison:

Figures 9, 8 & 10 shows comparison of control area frequency deviations and tie line power variations with Fuzzy and Anfis controller. The graphs emphasis change in tie line powers settling time of prescribed controllers. ANFIS controller provides quick settling time, comparative overshoot compare to FUZZY controller. ANFIS provides zero steady state error.

CONCLUSION:

In this paper, perceived that the dynamic performance of multi-source power generation Load frequency control achieved by employing FUZZY controller, ANFIS controller. The performance evaluation shows that both controllers provides satisfactory control of frequency, tie line power. Artificial intelligent controllers have wider adaptability of power plant environment. The effectiveness of ANFIS controller provides better controlling action. The comparison shows that Anfis controller gives lesser settling time with zero steady state error. ANFIS controller improves the dynamic performance of the two area multi source power system.
REFERENCES:


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BIOGRAPHIES

Mr.P.Ramalingaiah completed his B.Tech in MITS Madanapalle and did his M.Tech in GVIC Madanapalle. His areas of interests are Operation and control in power system. He is currently working as Assistant Professor in EEE department at Sir Vishveshwaraiah institute of Technology Madanapalle(SVTM).

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