A Wavelet based Multi Resolution Controller for Load frequency Control of Multi Area Deregulated Power System

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Abstract

This paper presents design of wavelet based multi resolution controller to deal with load frequency control problem of multi area power system under deregulated environment. This proposed novel control strategy shall take care of nonlinearities in an effective manner. This proposed controller is tested on open access two area power system under one possible contract scenario. The performance of proposed method is compared with normal PI controller.

1 Introduction

In power system load frequency control is more crucial problem due to frequency fluctuations there is a loss of economy to the country indirectly [1]. The fluctuation in loads causes the kinetic energy stored in the rotor altered [2], which affects the frequency deviations of the power system, due to frequency deviations, the undesirable operation of turbine and all power system components occurred [3]. Now a day’s load frequency control problem concern to deregulated power system is very much attracted by the researchers due to its complexity. In deregulated environment design of load frequency controller is very much difficult due to more number of input parameters and also rapidly varying load demands of DISCOMs [4-12].

In this paper a wavelet based multi resolution controller proposed to solve load frequency control of multi area power system. In the design of the controller a decomposition technique is used to decomposed unwanted frequency signal and noise levels are reduce. Due to reduction of noise levels, there may be an improvement in the system dynamic response. The performance of proposed wavelet controller is compared to conventional PI controller under possible contract scenario.

The remaining paper presented the following. Section 2 the modelling of deregulated Thermal – Thermal system bilateral contracts is discussed. Design of multi resolution wavelet controller described in section 3. In section 4 simulation results are presented. Finally conclusions are given in section 5.

2 Mathematical Modelling of Restructured Power System for LFC Problem

The dynamic model of two area thermal-thermal deregulated power system to address load frequency control problem is mentioned in Fig.2 [14-18].

The modelling of contracted demands and un-contracted demands are represented by $cpf$. The transactions of DISCOM with GENCO are represented by DPM matrix. The distribution of area control error between the areas is represented by $apf$.

The Area Control Error (ACE) is a function of frequency deviation and change in tie line power flow [19].

$$ACE_i = B_i \Delta f_{error} + \Delta P_{error} \quad i = 1, 2,$$

In deregulated power system the tie line power flow is a function of contract participation factor ($cpf$).

$$\Delta P_{tie\_2\rightarrow1\_scheduled} = \sum_{j=1}^{4} \sum_{i=3}^{2} c_{pfij} \Delta P_{tie} - \sum_{j=2}^{4} \sum_{i=1}^{2} c_{pfij}$$

$$\Delta P_{tie\_1\rightarrow2\_error} = \Delta P_{tie\_1\_scheduled} - \Delta P_{tie\_1\_act}.$$

The transactions of DISCOMS with GENCO are given by [20]

$$DPM = \begin{bmatrix} cf_{f_{11}} & cf_{f_{12}} & cf_{f_{13}} & cf_{f_{14}} \\ cf_{f_{21}} & cf_{f_{22}} & cf_{f_{23}} & cf_{f_{24}} \\ cf_{f_{31}} & cf_{f_{32}} & cf_{f_{33}} & cf_{f_{34}} \\ cf_{f_{41}} & cf_{f_{42}} & cf_{f_{43}} & cf_{f_{44}} \end{bmatrix}$$

The Area Control Error participation factor is represented by $apf$ for a multi-area power system consisting of $M$ generators in a control area [21].

$$\sum_{i=1}^{M} cf_{f_{ij}} = 1$$

The dotted and dashed lines in Fig.2 shows the load demand signals based on the possible contracts between GENCOS and DISCOs that carry information as to which GENCO have to follow a load demanded by that DISCO. These new information signals were absent in the traditional AGC scheme. The representation of two area power system with two plants is given in state space representation as [4]
The scaling function is a weighted sum of the shifted version is represented by
\[ \phi(2^m x) = \sum_{k} h(k) \phi(2^{m+1} x + k) \]
m+1 is number of approximations.
\[ y^{m+1} = y^m \oplus w^m \]
\( w^m \) is information added upon moving from the coarser \( f^m(x) \) to the finer \( f^{m+1}(x) \) while describing about original function.
\[ f^{m+1}(x) = f^m(x) + \sum_{n} \omega(2^m x - n) \]
Wavelet is represented by \( \psi(x) \) is related to scaling function as
\[ \psi(2^m x) = \sum_{k} g(k) \phi(2^{m+1} x - k) \]
A mixed form \( N \) – level multi resolution wavelet series representation of the signal \( f(x) \) is given by
\[ f(x) = \sum_{k} C_{m,k} \phi_{m,k}(N) + \sum_{n=m}^{\infty} d_m \psi_{m,n} k(x) \]
where \( C_{m,k} = \sum_{n} f(x) \cdot \psi_{m,n} k(x) \)
\[ d_m = \sum_{n} \psi_{m,n} \cdot k(x) \]
\( \phi(x) \), \( \psi(x) \) complement functions of \( \phi(x) \), \( \psi(x) \) respectively.
The most effective approach in finding out discrete wavelet transform (DWT) is
\[ h(k) = \sqrt{2} \sum_{n} \phi(x) \cdot \overline{\phi}(2x - k) \]
\[ g(k) = \sqrt{2} \sum_{n} \psi(x) \cdot \overline{\psi}(2x - k) \]
\[ g(k) = (-1)^{k} h(-kH) \]
The DWT consists of trend (c) and detailed coefficients (d). Initially in the analysis DWT we have to calculate the trend and detail signals. The trend signal attenuates the low frequency signal of original signal \( f(x) \). The detailed signal attenuates the high frequency signal of the \( f(x) \).
The output of multi resolution is the group of frequency signals at different frequency levels.
The combination of different frequency signals are summed at summing point.
\( f_H \), represents the high frequency signals and \( f_L \), represents the low frequency signals.
And N is the number of decomposition levels.

4 Simulation Results

In this section the performance of the proposed wavelet based MRPID controller has been studied under one possible contract scenario, simulations are performed for the contract scenario under various operating conditions and larger load demands.

In this scenario the performance of proposed controller is compared with conventional PI controller. The simulations are performed by using MATLAB-SIMULINK. The parameters for two area thermal – thermal system are given tables 1&2.

Contract scenario:
In this scenario, DISCO has the freedom to contract with any GENCO in there and other areas. So, the entire DISCOs contract with the GENCos for power based on following DPM.

\[
\text{DPM} = \begin{bmatrix}
0.2 & 0.3 & 0.5 & 0.0 \\
0.3 & 0.2 & 0.0 & 0.7 \\
0.5 & 0.0 & 0.2 & 0.1 \\
0.0 & 0.5 & 0.3 & 0.2
\end{bmatrix}
\]
It is considered that each DISCO demands 0.1puMW total power from other GENCOs as defined by entities in DPM and these GENCOs participate in AGC based on the following apfs.

\[
apf_1 = 0.6, \ apf_2 = 1 - apf_1 = 0.4  \\
apf_3 = 0.6, \ apf_4 = 1 - apf_3 = 0.4
\]

In steady state any GENCO generation must match the required load of the DISCOs in contact with it. It is expressed as

\[
\Delta P_{mi} = \sum_j c_p f_{ij} \Delta P_{ij}
\]

So, for this scenario we have

\[
\Delta P_{m1} = 0.2 \Delta P_{L1} + 0.3 \Delta P_{L1} + 0.5 \Delta P_{L2} + 0.1 \Delta P_{L2} = 0.1 \text{puMW}
\]

\[
\Delta P_{m2} = 0.12 \text{puMW}; \quad \Delta P_{m3} = 0.08 \text{puMW}; \quad \Delta P_{m4} = 0.1 \text{puMW}
\]

The results for this case are given in the following figures. Fig. 4 represents Frequency deviation of control area-1, Fig. 5 represents frequency deviation of control area-2 and Fig. 6 represents Deviation in tie-line power exchange.

**Table 1: % of peak overshoots in change of frequency in CA-1, CA-2 after introducing different controllers.**

<table>
<thead>
<tr>
<th>Name of the controller</th>
<th>% of overshoot in frequency deviation in CA-1</th>
<th>% of overshoot in frequency deviation in CA-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Wavelet Controller</td>
<td>90%</td>
<td>85%</td>
</tr>
</tbody>
</table>

**Table 2: The settling time of frequency deviations in CA-1 and CA-2**

<table>
<thead>
<tr>
<th>Name of the controller</th>
<th>Settling time of CA-1 (frequency deviation)</th>
<th>Settling time of CA-2 (frequency deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>Not settled even after 20 sec</td>
<td>Not settled even after 20 sec</td>
</tr>
<tr>
<td>Wavelet Controller</td>
<td>12 sec</td>
<td>12 sec</td>
</tr>
</tbody>
</table>

**Appendix**

The power system parameter values are given in Table 3 & 4 for Thermal – Thermal system.

**Table 3: GENCO parameters**

<table>
<thead>
<tr>
<th>GENCOs parameter</th>
<th>Area1 Genco -1</th>
<th>Area1 Genco -2</th>
<th>Area2 Genco -3</th>
<th>Area2 Genco -4</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_r(S) )</td>
<td>0.32</td>
<td>0.30</td>
<td>0.03</td>
<td>0.32</td>
</tr>
<tr>
<td>( T_e(S) )</td>
<td>0.06</td>
<td>0.08</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>( R(\text{Hz/pu}) )</td>
<td>2.4</td>
<td>2.5</td>
<td>2.5</td>
<td>2.7</td>
</tr>
</tbody>
</table>

**Table 4: Control Area parameters**

<table>
<thead>
<tr>
<th>Control Area Parameters</th>
<th>Area-1</th>
<th>Area-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K_p(\text{puHz}) )</td>
<td>102</td>
<td>102</td>
</tr>
<tr>
<td>( T_e(S) )</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>( B(\text{puHz}) )</td>
<td>0.425</td>
<td>0.396</td>
</tr>
</tbody>
</table>
5 Conclusions

In this paper a wavelet based multi resolution controller is proposed to LFC problem of multi area power system. This wavelet based multi resolution controller eliminates unwanted frequency signals effectively and exhibits good dynamic response (low overshoot and low settling time) compared to the conventional PI controller. The overshoot and settling time is very much attractive with wavelet controller compared to conventional PI controller.

References


