Performance of Automatic Generation Control in an Interconnected Power System under Deregulated Environment

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ABSTRACT
In this paper the Automatic Generation Control (AGC) in interconnected power system under deregulated environment to control the tie line power of the interconnected hydro-thermal power system in which thermal reheated turbine is used. All four areas have different number of GENCOS, DISCOS and TRANSCOS. A DISCO can individually and multilaterally contracts with a GENCO for power requirements and these transactions are done under the ISO supervision. After deregulation, the bilateral contract on the dynamics of automatic generation control (AGC), DPM has been used. The control strategies guarantees that the steady state error of frequencies and inadvertent interchange of tie-lines power are maintained in a given tolerance limit. The study is carried out on IEEE 75-bus system. The performances of the controllers are simulated using MATLAB/SIMULINK package.

Keywords - Automatic Generation Control (AGC), GENCO, CPF, DISCO, DPM, TRANSCO.

I. INTRODUCTION
The automatic generation control (AGC) is a technical requirement for the proper operation of an interconnected power system. Automatic generation control is very important in power system operation and control for supplying sufficient and reliable electric power with good quality. In cases of area load changes and abnormal conditions, such as mismatches in frequency and inadvertent interchange of tie-lines power are caused. These mismatches are corrected by controlling the frequency. To attain zero steady state error and to maintain the system frequency constant, a control scheme is needed. Here study of the four area restructured power system is done in which each area has its own automatic generation controller (AGC) which maintains the tie line power and system frequency constant by varying the generation according to the area control error (ACE). The AGC varies the set position of generators of that area, which minimize the average time of ACE (Area Control Error).

II. RESTRICTURED POWER SYSTEM
A deregulated electricity market comprises of many players such as generator owners (GENCO’s), load supply entities (DISCO’s), and transmission owners (TRANSCO’s). Each market has an independent grid operator, known as the ISO (independent system operator), responsible for the day-to-day and, long-term operation of the power system. Restructured power system is needed which is basically divided into three parts GENCOS (generating companies), TRANSCOs (transmission companies), and DISCOS (distribution companies). The GENCOS generates power and DISCOS have freedom to have contract with any generating company for the sake of power trading. To visualize the contracts between GENCOS and TRANSCOs, the concept of DISCO participation matrix (DPM) is used. DISCO participation matrix is in the form of rows and columns where row represents number of GENCOS and columns represents number of DISCOS. In a deregulated system GENCOS sell power to DISCOS at competitive price and hence, DISCOS have various options for the transaction of power from any of the GENCOS of its own area or different area. In each area, an automatic generation controller (AGC) supervises the tie line power and system frequency, also computes the net change in the generation required which is related to the area control error (ACE) and changes the set position of the generators with in that area due to which net average time of ACE is at minimum.

Fig.1. Configuration of power system under deregulated environment.
In DPM diagonal element shows the local demand. The demand of one region discos value to another regions Genco value is shown by the off diagonal element. The actual and scheduled steady state power flows on the given tie line is:

\[ \text{Ptie}_{i,j, \text{schedule}} = [ \text{Demand from genco of area i by disco of area j –Demand from genco of area j by disco of area i}] \]

The tie line error is given by:

\[ \text{Ptie}_{i,j, \text{error}} = \text{Ptie}_{i,j, \text{actual}} - \text{Ptie}_{i,j, \text{schedule}}. \]

The tie line error disappear the steady state error. The ACE signal given to the ISO is:

\[ \text{ACE}_i = B_i \Delta f_i + \Delta \text{Ptie}_{i,j} \]

The schedule tie line powers are:

\[ \Delta \text{Ptie}_{1\text{-}2, \text{schedule}} = -(0.2 \times 0.1 + 0.3 \times 0.1) + (0.1 \times 0.1) = 0.02 \text{pu} \]
\[ \Delta \text{Ptie}_{2\text{-}3, \text{schedule}} = -(0.1 \times 0.1) = -0.01 \text{pu} \]
\[ \Delta \text{Ptie}_{3\text{-}4, \text{schedule}} = (0.5 \times 0.1 + 0.2 \times 0.1 + 0.5 \times 0.1) + (0.4 \times 0.1) = 0.08 \text{pu} \]
\[ \Delta \text{Ptie}_{4\text{-}2, \text{schedule}} = 0.2 \times 0.1 = 0.02 \text{pu} \]
\[ \Delta \text{Ptie}_{2\text{-}4, \text{schedule}} = 0.3 \times 0.1 + (0.2 \times 0.1 + 0.1 \times 0.1 + 0.2 \times 0.1) - (0.2 \times 0.1 + 0.2 \times 0.1) = 0.06 \text{pu} \]
\[ \Delta \text{Ptie}_{3\text{-}4, \text{schedule}} = -0.5 \times 0.1 + 0.2 \times 0.1 = 0.09 \text{pu} \]

**A. Bacterial foraging optimization technique**

It is recently developed technique, named as Bacterial foraging optimization (BFO) which has been projected by Passion based on a bacteria. The BF technique dependent on the deportation of E.coli bacteria which is found in the human intestine. The bacterial foraging optimized the controller gains and other parameters. In simulation work the parameter for coding is to be \( S=20, N_c=8, N_s=3, N_r=15, N_e=2, P_e=0.80 \).

\[ D(\text{attr.})=0.003, W(\text{attr.})=0.04, H(\text{repellent})=0.003, W(\text{repellent})=10 \] and \( P=10 \) considered.

\[ J = (\int \theta f_i^2 + (\text{Ptie})^2) \text{dt} \]

**B. Result And Analysis**

The simulation is carried out on Four-Area interconnected deregulated system. The PI controller is implemented with and without bacterial foraging technique. In this, tie line power of the system is compared. The simulation result are shown in fig(3) to fig(23). Using Simulink/MATLAB formulation the optimum AGC controller gain value, representing the scheduling of generators, tie line power exchange are done. With the help of BF algorithm value of Ki is obtained, which is applied to AGC in interconnected four area system under the deregulated environment.

**C. Tie-line power comparison of different areas**

![Graph showing Del Ptie1-2 with and without BF controller](www.ijsret.org)
Fig. 4. DelPtie1-3 with and without BF controller

Fig. 5. DelPtie1-4 with and without BF controller

Fig. 6. DelPtie2-3 with and without BF controller

Fig. 7. DelPtie2-4 with and without BF controller
Fig. 8. DelPtie3-4 with and without BF controller

Fig. 9. Del Pg1 with and without BF controller

Fig. 10. Del Pg2 with and without BF controller

Fig. 11. Del Pg3 with and without BF controller
Fig. 12. Del Pg4 with and without BF controller

Fig. 13. Del Pg5 with and without BF controller

Fig. 14. Del Pg6 with and without BF controller

Fig. 15. Del Pg7 with and without BF controller
Fig. 16. Del Pg8 with and without BF controller

Fig. 17. Del Pg9 with and without BF controller

Fig. 18. Del Pg10 with and without BF controller

Fig. 19. Del Pg11 with and without BF controller
Fig. 20. Del Pg12 with and without BF controller

Fig. 21. Del Pg13 with and without BF controller

Fig. 22. Del Pg14 with and without BF controller

Fig. 23. Del Pg15 with and without BF controller
Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>Δ</td>
<td>Deviation</td>
</tr>
<tr>
<td>s</td>
<td>Different in terms of Laplace</td>
</tr>
<tr>
<td>f</td>
<td>Frequency</td>
</tr>
<tr>
<td>ω</td>
<td>Angular Speed</td>
</tr>
<tr>
<td>Tg</td>
<td>Governor Time Constant</td>
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<tr>
<td>Tij</td>
<td>Coefficient of i-j tie Line</td>
</tr>
<tr>
<td>aij</td>
<td>Operator</td>
</tr>
<tr>
<td>Bi</td>
<td>Bias Factor</td>
</tr>
<tr>
<td>Pref</td>
<td>The Output of ACE</td>
</tr>
<tr>
<td>Pl</td>
<td>Electric Load Variations</td>
</tr>
<tr>
<td>R</td>
<td>Regulation Parameter</td>
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<tr>
<td>Apfi</td>
<td>ACE Participation Factors</td>
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<tr>
<td>DPM</td>
<td>DISCO Participation Matrix</td>
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<tr>
<td>cpfi</td>
<td>Contract Participation Factors</td>
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<tr>
<td>ACE</td>
<td>Area Control Error</td>
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<tr>
<td>Pi-jactual</td>
<td>Real Tie Line Power</td>
</tr>
<tr>
<td>Pi-j-scheduled</td>
<td>Scheduled Tie Line Power Flow</td>
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<tr>
<td>Pi-j</td>
<td>Error Tie Line Power Error</td>
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<tr>
<td>BF</td>
<td>Bacterial Foraging</td>
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<tr>
<td>Kp1,2,3</td>
<td>Generator Gain Constant</td>
</tr>
<tr>
<td>Tp1,2,3</td>
<td>Generator Time Constant</td>
</tr>
<tr>
<td>Pt</td>
<td>Turbine Output Power</td>
</tr>
<tr>
<td>Tt</td>
<td>Turbine Time Constant</td>
</tr>
<tr>
<td>Pg</td>
<td>Governor Output Power</td>
</tr>
<tr>
<td>Tg</td>
<td>Governor Time Constant</td>
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III. CONCLUSION

This Paper encapsulates automatic generation control of the power system after deregulation includes bilateral contracts. DPM facilitates bilateral contracts simulation. Controller gains are optimized by both Bacterial Foraging and Proportional integral controller. This is study using simulation on a Four area power system considering different contracted scenarios. The dynamic and steady state responses for tie line power and power generation changes are shown. The simulation reveals that the proposed Bacterial Foraging based integral controller gives better performance than Proportional integral controller.

APPENDIX-1

Base =1000MVA

- $a_{12} = a_{13} = a_{14} = a_{23} = a_{24} = a_{34} = 1$

**Thermal Data**

- $T_p = 20s$
- $T_{ij} = 0.086s$
- $t_{ij} = -1$
- $T_t = 0.3s$
- $R = 2.4 hz/pu . Mw$
- $Kp_i = 120 hz/pu. Mw$
- $T_g = 0.08s$

**Hydro Data**

- $T_p = 20s$
- $T_w = 1s$
- $T_{ms} = 48.7s$
- $K_d = 5 hz/pu.Mw$
- $T_d = 0.1s$
- $F = 60 hz$
- Time constant ($T_p$)=2H/BF
- ΔPd1= ΔPd2 = ΔPd3 = 0.01
- Governor time constant ($T_g$)
- $T_{g1}=T_{g2} = 0.08 sec$
- $T_{p1}=T_{p2}=T_{p3}=20 sec$
- Frequency Bias Factor (B)
- $B_1= B_2 = B_3 = B_4 = 0.425$
- Speed Regulation (R)

$1/R = 0.417$

REFERENCES


