# Optimal PID Tuning for AGC system using Adaptive Tabu Search

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*Abstract:* - This paper presents an application of the intelligent search technique for the parameters optimization of conventional automatic generation control (AGC) systems. An efficient intelligent search technique, which is Adaptive Tabu Search (ATS), is employed to demonstrate the effectiveness of the intelligent search techniques in the tuning of the AGC parameters. A two-area non-reheat thermal system is considered to be equipped with PID controllers to depict the optimum parameter search. Parameters of these PID controllers are obtained using Adaptive Tabu Search technique. The same parameters are also turned using the Ziegler-Nichols method. The performance of the proposed controller has been evaluated with the performance of the conventional integral controller and the conventional Ziegler-Nichols PID tuning controller in order to demonstrate the superior efficiency of the proposed ATS based PID controller. By comparison with the conventional technique, the effectiveness of the anticipated scheme is confirmed.

*Key-Words:* - Automatic generation control, intelligent search technique, PID tuning, Adaptive Tabu Search , Optimization, Power systems

## 1 Introduction

Normally, a large scale electric power system consists of many interconnected control area or regions representing coherent groups of generators. For good quality of electric power and high reliability of power system, load frequency control (LFC), or automatic generation control (AGC), is very important issue in power system operation and control [1].

The optimal and automatic operation of thermal power systems is currently performed by economic dispatch (ED) and Load Frequency Control (LFC). ED transfers optimal unit base points and economic participation factors to LFC. This interaction between LFC and ED is aimed at minimizing the fuel cost, while reducing the area control error (ACE) and the number of unit control actions.

Mismatches in frequency and scheduled tie-line power flows between interconnected control areas can be occurred in cases of area load changes and abnormal conditions, such as outages of generation and varying system parameters. Such mismatches are corrected by controlling the frequency, which is defined as the regulation of the power output of generators within a prescribed area [2].

A net interchange tie-line bias control strategy has been widely accepted by utilities. The frequency and the interchanged power are kept at their desired values by means of feedback of the area control error (ACE) integral, containing the frequency deviation and the error of the tie line power, and controlling the prime movers of the generators.

The objective of the Classical AGC or the LFC is to satisfy the following requirements [2,3,4]: (i) Zero steady state errors in tie-line exchanges and frequency deviations. (ii) Optimal transient behaviours (iii) In steady state, the power generation levels should satisfy the optimal dispatch conditions.

The key assumptions of the Classical AGC or the LFC are:

(a) The steady-state frequency error following a step load change should vanish. The transient frequency and time errors should be small.

(b) The static change in the tie power following a step load in any area should be zero, provided each area can accommodate its own load change. Be assisted from other areas.

(c) Any area in need of power during emergency should be assisted from other area.

The transient performance of the interconnected power system with respect to the control of the frequency and tie line powers obviously depends on the value of the integral gain and the frequency bias.

Over the past decades, many control strategies for AGC of power systems such as linear feedback [5], optimal control [6] and variable structure control [7-8] have been proposed in order to improve the transient response.

With advancement in control technology, control methods based intelligent search techniques have been purposed to provide better AGC system. These methods are based on Genetic Algorithm [8-10], Neural Network [11-15] and Fuzzy system theory [16-20].

A digital simulation is used in conjunction with the adaptive tabu search optimization process to determine the optimum parameters of the AGC for each of the performance indices considered. Adaptive tabu search are used as parameter search techniques to find near optimal solutions.

In addition to the conventional AGC, a more elaborate feedback control strategy, namely PID control is also investigated. In this case the feedback control signal is a linear combination of the ACE and its integral. The feedback gain parameters for such controls are also optimized using genetics algorithms. A two- area non-reheat thermal system is considered in this paper to demonstrate the suggested technique.

## 2 Problem Formulation

Non-reheat type two-area thermal generating system represents by block diagram of closed loop controlled system model[7,8,17]. As shown in Fig. 1, $f$ is the system frequency (Hz), $R_i$ is regulation constant (Hz/unit), $T_g$ is speed governor time constant (sec), $T_t$ is turbine time constant (sec) and $T_p$ is power system time constant (sec). State of the overall system can be described as a multi-variables state equation in the following form

$$\dot{x} = Ax(t) + Bu(t) + Ld(t) \tag{1.1}$$

where $A$ represents the system matrix, $B$ and $L$ the input and disturbance distribution matrices, and $x(t)$, $u(t)$ and $d(t)$ represent state, control signal and load change disturbance vectors, respectively.

$$x(t) = \begin{bmatrix} \Delta f_1 & \Delta P_{g1} & \Delta P_{t1} & \Delta P_{tie} & \Delta f_2 & \Delta P_{g2} & \Delta P_{t2} \end{bmatrix}^T \tag{1.2}$$

$$u(t) = \begin{bmatrix} u_1 & u_2 \end{bmatrix}^T \tag{1.3}$$

$$d(t) = \begin{bmatrix} \Delta P_{d1} & \Delta P_{d2} \end{bmatrix}^T \tag{1.4}$$

where Δ denotes deviation from the setting values and $u_1$ and $u_2$ are the control signals in area 1 and 2, respectively.

The system output, which depends on area control error (ACE) is given as

$$y(t) = \begin{bmatrix} y_1(t) \\ y_2(t) \end{bmatrix} = \begin{bmatrix} ACE_1 \\ ACE_2 \end{bmatrix} = Cx(t) \tag{1.5}$$

$$ACE_i = \Delta P_{tie} + b_i \Delta f_1 , \quad i = 1,2 \tag{1.6}$$

where $b_i$ is the frequency bias constant, $\Delta f_i$ is the frequency deviation, $\Delta P_{tie}$ is the change in tie-line power for area i and C is the output matrix.

Basically, electric power system components are non-linear, therefore a linearization around a nominal operating point is usually performed to get a linear system model which is used in the controller design process. The operating conditions of power systems are continuously changing. Accordingly, the real plant usually differs from the assumed one. Therefore, classical algorithms to design an automatic generation controller using an assumed plant may not ensure the stability of the overall real system.

For the two area non-reheat thermal system considered in this study, the conventional integral controller was replaced by a PID controller with the following structure [21]

$$G_c(s) = K_P \left( 1 + \frac{1}{T_I s} + T_D s \right) \tag{1.7}$$

where $K_p$ is proportional gain, $T_i$ and $T_d$ are integral and derivative time constants, respectively. The PID controllers in both the areas were considered to be identical. The control signal for the conventional PID controller can be given in the following equation.

$$U_i(s) = -G_c(s) \times ACE_i(s)$$

$$U_i(s) = -K_P \left( 1 + \frac{1}{T_I s} + T_D s \right) (\Delta P_{tie} + b_i \Delta f_i) \tag{1.8}$$

Now a performance index can be defined by adding the sum of squares of cumulative errors in ACE, hence based on area control error a performance index J can be defined as:

$$J = \int_0^\infty \sum_{i=1}^{2} (ACE_i)^2 dt \tag{1.9}$$

Based on this performance index $J$ optimization problem can be stated as:

$$Minimize \quad J \tag{1.10}$$

Subjected to :

$$\begin{aligned} K_{P,j}^{min} \le K_{P,j} \le K_{P,j}^{max} & \\ K_{I,j}^{min} \le K_{I,j} \le K_{I,j}^{max} & \quad : j = 1,2 \\ K_{D,j}^{min} \le K_{D,j} \le K_{D,j}^{max} & \end{aligned} \tag{1.11}$$

$K_{P,j}$, $K_{I,j}$ and $T_{D,j}$ are PID controller parameter of $j^{th}$ area.

To simplify the study, the two interconnected areas were considered identical. The optimal parameter are such that $G_{c1} = G_{c2} = G_c$ and

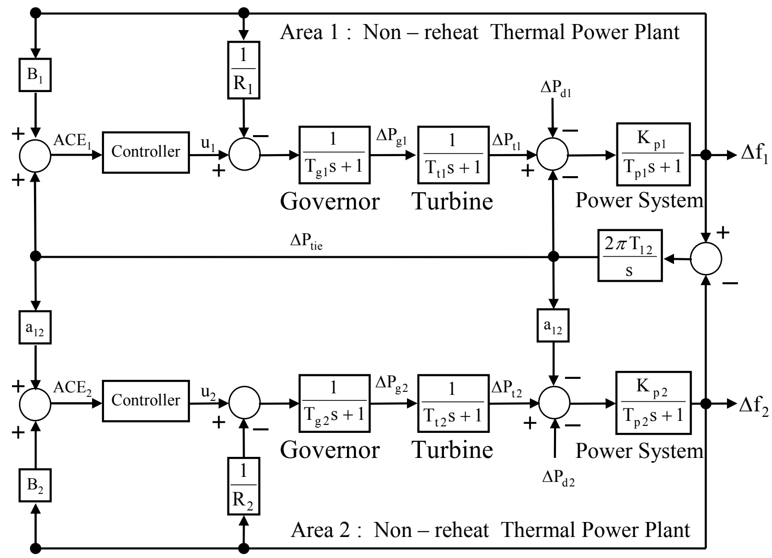


Fig. 1. Two-area interconnected power system with controller.

$B_1 = B_2 = B$. The nominal system parameters are[3]: $T_{g1} = T_{g2} = 0.4$ sec, $T_{t1} = T_{t2} = 0.5$ sec, $T_{p1} = T_{p2} = 20$ sec, $K_{p1} = K_{p2} = 100$, $R_1 = R_2 = 3$, $B_1 = B_2 = 0.425$, $2\pi T_{12} = 0.05$, $a_{12} = 1$.

## 3. Adaptive Tabu Search Algorithm

The tabu search (TS) algorithm is an iterative search that starts from some initial feasible solution and attempts to determine a better solution in the manner of a hill-climbing algorithm. TS is commonly developed for solving local optimization problem. The algorithm keeps historical local optima for leading to the near-global optimum fast and efficiently. The local optima are kept in Tabu List (TL) for making sure that there will be no same local optimum happening again in the process. Another powerful tool in TS is called backtracking. Backtracking process starts from stepping back to some local optimum in TL and then searching a new optimum in different directions. Backtracking is performed when the backtracking criterion (BC) is encountered.

The TS algorithm has a flexible memory in which to maintain the information about the past step of the search and uses it to create and exploit the better solutions. The main two components of the TS algorithm are the tabu list (TL) restrictions and the aspiration criterion (AC). Well description and detail of adaptive tabu search (ATS) can be found in [22-26].

In applying the ATS algorithm, to solve a combinatorial optimization problem, the basic idea is to choose a feasible solution at random and then obtain a neighbor to this solution. A move to this neighbor is performed if either it does not belong to the TL or, in case of being in the TL it passes the AC test. During these search procedures the best solution is always updated and stored aside until the stopping criterion is satisfied [27].

The following notations are used through the description of the ATS algorithm for a general combinatorial optimization problem:

- $X$ : the set of feasible solutions.
- $x$ : the current solution, $x \in X$
- $x_b$ : the best solution reached.
- $x_{nb}$ : the best solution among trial solutions.
- $E(x)$ : the objective function of solution x
- $N(x)$ : the set of neighborhood of $x \in X$
- $TL$ : tabu list.
- $AL$ : aspiration level.

The procedure of the ATS algorithm is as follow:

**Step 0**: Set TL as empty and AC as zero.

**Step 1**: Set iteration counter $k = 0$. Select an initial solution $x \in X$, and set $x_b = x$.

**Step 2**: Generate a set of trial solutions in the neighborhood of x. Let $x_{nb}$ be the best trial solution.

**Step 3**: If $E(x_{nb}) > E(x_b)$, go to Step 4, otherwise set the best solution $x_b = x_{nb}$ and go to Step 4.

**Step 4**: Perform the tabu test. If $x_{nb}$ is NOT in the TL, then accept it as a current solution, set $x = x_{nb}$, and update the TL and AC and go to Step 6, otherwise go to Step 5.

**Step 5**: Perform the AC test. If satisfied, then override the tabu state, set $x = x_{nb}$ , and update the AC.

**Step 6**: Perform the termination test. If the stopping criterion is satisfied then stop, otherwise - Activate the AR (adaptive search redius) mechanism to speed up the searching process. - Activate the BT mechanism if a local minimum trap occurs. Reset Iteration and repeat step 2.

Based on ATS algorithm, PID controller can be identified using the flow chart show in Fig.3.

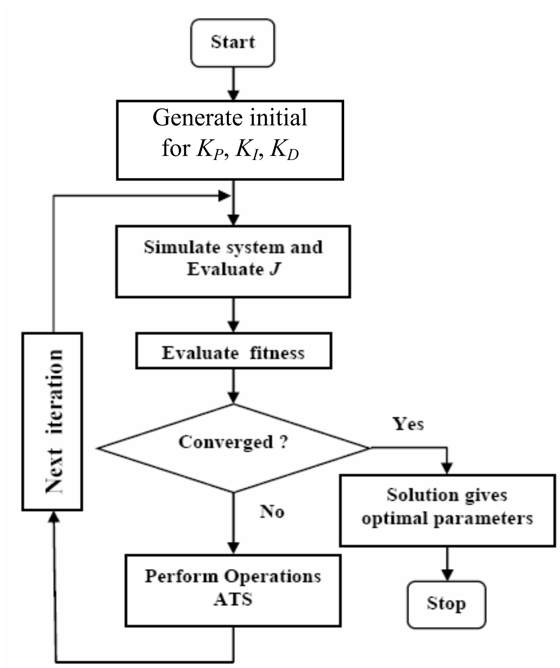


Fig. 3 Flow chart for the ATS process

Although in this paper, the PID controller parameters were obtained using adaptive tabu search technique. For comparison, however, the PID controller parameters were also obtained using the conventional Zeeigler-Nichols tunning technique [20]

## 4 Results and Discussions

By using ATS techniques conjunction with equation (1.9)-(1.11), optimal controller parameters were obtained as shown in Table 1.

Table 1 Optimal Controller Parameter after using ATS technique.

| | $K_P$ | $K_I$ | $K_D$ |
|---|---|---|---|
| Area 1 | 69.3590 | 63.9335 | 94.7953 |
| Area 2 | 69.3590 | 63.9335 | 94.7953 |

Performance of the ATS based PID controller was compared with the integral controller and conventionally tuned PID controller the gain of this integral controller was taken as 0.09 for both the areas.

Fig. 4, Fig. 5, Fig. 6 and Fig.7 show the time domain performance of The ACG system with ATS turned controller. System was simulated for 25 seconds with step change of 0.1 pu. in load of area1. Disturbance was given at $t = 0.1$ sec. Time response with conventional integral controller and the conventional PID controller are also plot.

As seen in the time response, the ATS tuned controller gives better performance in terms of overshoot and setting time the ATS based controller oscillations are damped out within 4 sec. this shows the efficacy of the ATS tuned PID controller over the performance of the conventional integral controller and the conventionally tuned PID controller ( Ziegler-Nichols method ).

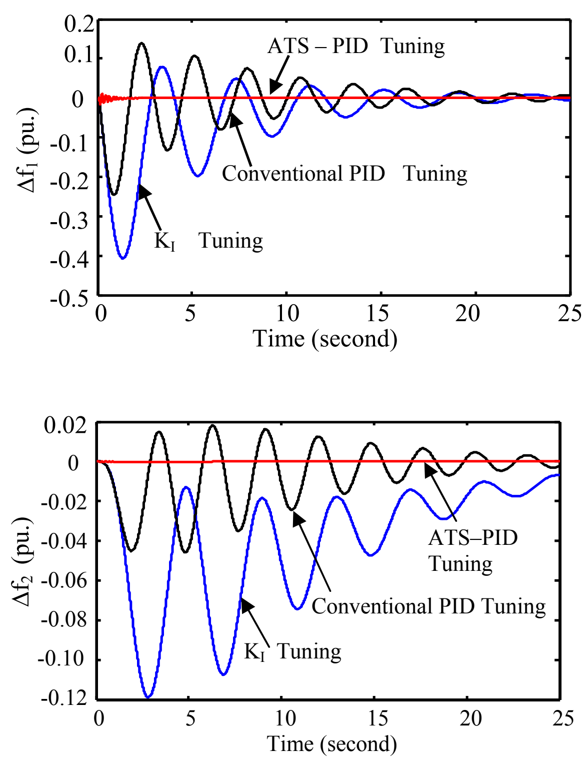


Fig. 4 Variation of frequencies due to step change in load ($\Delta P_{D1}$= 0.1 pu.)

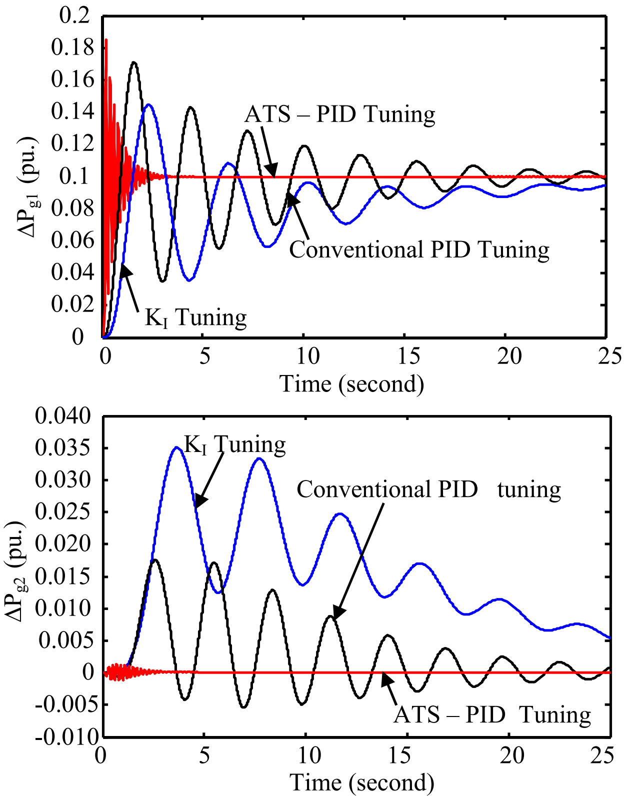


Fig. 5 Variation of generator powers due to step change in load ($\Delta P_{D1}$= 0.1 pu.)

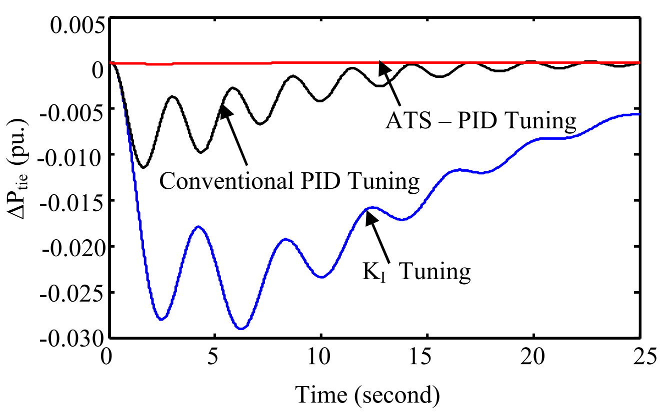


Fig. 6 Variation of tie – line powers due to step change in load ($\Delta P_{D1}$= 0.1 pu.)

## 5 Conclusion

The results illustrated in this paper show that adaptive tabu search technique could be used for tuning and designing more efficient AGC controllers. The advantage of ATS technique is that it is independent of the complexity of performance index considered. Performance evaluation of ATS based controller on a two area non-reheat system shows that its performance is far better than that

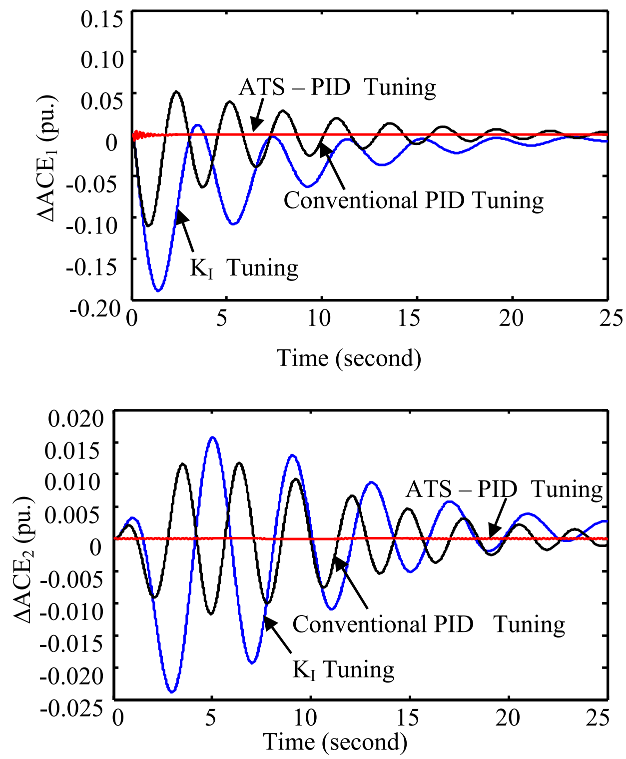


Fig. 7 Variation of area control error due to step change in load ($\Delta P_{D1}$= 0.1 pu.) in area 1

could be obtained by conventionally tuned controller. In addition, the design procedure is simple and bears much potential for practical implementation.

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