Automatic generation control for single area power system using GNA tuned PID controller

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Abstract. This work investigates Automatic Generation Control in the one area thermal power system and optimization of gain parameters of conventional controller for non-reheat and reheat thermal power systems. Proportional – integral – derivative (PID) controller and PI controller is used for the comparison. The tuning of controller gain parameters is obtained by Integral Time Absolute Error (ITAE) approach for optimization. The proposed work utilizes new meta-heuristic algorithm for tuning of controller gain parameters. The GNA algorithm proved to be effective and robust for tuning a controller in the presence and absence of appropriate Generation Rate Constraint (GRC). The performance comparison and verification of simulation results is shown in time domain using Matlab. Finally, simulation result reveals that new GNA tuned PID controller provides more superior response in comparison to PI controller with and without including the effect of GRC.

1. Introduction

The problem of frequency deviation due to change in the load demand is a serious problem faced in the interconnected power systems [1]. High quality of power supply [2] is needed due to modernized and automated industries. The mismatch between the power generated and consumed is occurred due to changes in the load demand. In the single area power system, power quality will be good when load demand occurs within the specified limit. The automatic generation control [3] scheme of the power systems can be done to keep the reliability of a stable frequency. Deviation in frequency for the single area and two area power systems [4] was discussed by Kothari with generation rate constraint [5] and integral controller. He also introduced the Proportional Integral controller [6] in the AGC of two area reheat thermal power systems [7]. Gozde [8] introduced the AGC of reheat thermal power system using artificial bee colony algorithm. In the recent years new algorithms have been introduced such as bacteria foraging algorithm (BFOA) [9], genetic algorithm (GA) [10], particle swarm optimization (PSO), teaching learning based optimization (TLBO) [11] for tuning of PID [12] controller parameters. From the study of preceding literature it is observed that several controllers are used in the AGC of single area and two area power systems to control the frequency deviation. The PID controllers are widely used industrial controllers. It improves the dynamic response with minimum steady-state error for any type of a system. Therefore the global neighbourhood algorithm (GNA) [13]
is used to optimize the PID controller parameters for better performance. The gain parameters of PID controller are compared with gain parameters of proportional integral controller.

2. Modelling of AGC in Single Area Power System (SAPS)

The major sources of power generation to meet the load demand are from hydro and thermal units. AGC strategies for several different power system structures such as single area, two-area and multi-area power system have been discussed by researchers. SAPS consists of a speed governor, a turbine and a generator with a primary controller as well as supplementary controller. In the SAPS one generating unit is present which is responsible to maintain the desired frequency. The power system can be classified into non-reheat and reheat type of power system. The BD of a SANPS with the components connected is shown in figure.1.

Figure 1. BD of a SANPS.
In a power system a governor regulates the speed of a machine and senses the frequency bias. Governor helps to start the turbine with regulated speed and also protects it from hazard conditions. The governor input is change in reference power and the change in compensated power $\Delta P_{err} = (\Delta P_{ref} - \Delta P_c)$ and output is the corresponding valve setting change $\Delta P_v$. The primary speed control is given by the equation (1)

$$\Delta P_c = \frac{1}{R} \Delta F$$

Frequency deviation is $\Delta F$. The turbine converts the energy of steam or water into mechanical power. The turbine drives the generator by this mechanical power. The types of turbines used are: reheat, hydraulic and non-reheat turbines. The change in valve setting $\Delta P_v$ is the input for the turbine and output is change in mechanical power $\Delta P_m$. Transfer function of a non-reheat turbine, $G_T(s)$ and a reheat turbine, $G_{TR}(s)$ is represented by equation (2) and equation (3) respectively

$$G_T(s)=\frac{1}{1+sT_{T}}$$

$$G_{TR}(s)=\frac{1+sK_{T}T_{T}}{(1+sT_{T})(1+sT_{r})}$$

The generator and load transfer function is represented by $G_P(s)$ in equation (4). The effect of the reheat turbine on the single area system is shown in the dynamic response. The BD of a SARPS with the components connected is shown in figure.2

3. Model of a SAPS with GRC

The different types of non-linearity can be present in a power system. In this model generation rate constraint (GRC) is considered. The BD of a turbine system with GRC is shown in figure.3. The system performance degrades in the presence of GRC. Using a PI or a PID controller the dynamic response improves. The value of generation rate is 0.1 p.u.MW/min, i.e., $\pm 0.00017$ p.u. MW/s.
4. Controller design

The use of PI and PID controllers are very often used in industry. The proportional integral controller is designed from the combination of the proportional and integral controllers. PI controller design has the proper combination of $K_P$ and $K_I$ parameters optimized using GNA algorithm. It will minimize the forced oscillations and steady state error from the time response. The proportional integral controller decreases the steady state error and the system stability is unaffected. The BD of a proportional integral controller with negative unity feedback closed loop is shown in figure 4. The PID controller is also a three term controller. It is the combination of the outputs of proportional, integral and derivative controllers. The PID controller has the advantages of both the PI and PD controllers. It improves the stability of the control system and the steady state error decreases. Where $K_P$, $K_I$, $K_D$ are the proportional constant, integral constant, derivative constant respectively. The transfer function of PI and PID controllers are $G_{PI}(s)$ and $G_{PID}(s)$ represented by equations (5) and (6) respectively:

\[
G_{PI}(s) = K_p + \frac{K_i}{s}
\]

\[
G_{PID}(s) = K_p + \frac{K_i}{s} + K_D s
\]

The BD of a PID controller parallel form is shown in figure 5. The BD of a SANPS with a controller is shown in figure 6. The BD of a SARPS with GRC and a controller with the components connected is shown in figure 7.

5. GNA algorithm

In this paper a new meta-heuristic algorithm is proposed to solve the optimization of problems in power systems. Alazzam and Lewis [13] introduced this global neighbourhood algorithm (GNA). A meta-heuristic [14] algorithm is a stochastic search algorithm. It searches by simulating the biological or natural selection methods. In the past few decades some algorithms are developed on the behavioral study of different animals such as tabu search (TS) [15], the ant colony algorithm (ACA) [16], Particle Swarm Optimization (PSO) [17]. Different algorithms proposed can be shown with the help of a pie-chart in figure 8. Like genetic algorithm (GA), ant colony algorithm (ACA), evolutionary algorithm GNA is derivative free and population based algorithm. The global and local search can be balanced by the principal of GNA algorithm. This can be explained as: First generate a set of random solutions
from entire search space, then the optimal value is obtained from the best solution. Then algorithm
iterates to give two sets of generated solutions in each iteration: one of the solution is obtained through
the global search space and the second set of solutions is generated from the neighborhood of the best
solution. The gain parameters $K_P$, $K_I$ and $K_D$ are shown in table 1 and table 2 obtained by the
simulation using GNA algorithm.

\[ J = \int_0^{\infty} |\Delta F| \, dt \]  

(7)

The comparison of the gain parameters $K_P$, $K_I$ and $K_D$ are given by the simulation result using GNA
algorithm. This algorithm is simulated for N=40 iterations and the best optimized parameters are
obtained. The value of gain parameters $K_P$, $K_D$, $K_I$ and ITAE are compared in the following tables 1 and table 2.

| Type of Model | Type of controller used | $K_P$  | $K_I$  | $K_D$  | ITAE  |
|---------------|-------------------------|--------|--------|--------|-------|
| SANPS         | PI                      | 0.3075 | 0.4681 | 0      | 0.0314|
| SANPS         | PID                     | 2.2814 | 4.6887 | 0.4279 | 0.0006|
| SARPS         | PI                      | 1.5387 | 1.2359 | 0      | 0.0633|
| SARPS         | PID                     | 3.2531 | 4.5221 | 0.5535 | 0.0077|

Table 2. Comparison of $K_P$, $K_I$, $K_D$ and ITAE for SAPS with GRC

| Type of Model | Type of controller used | $K_P$  | $K_I$  | $K_D$  | ITAE  |
|---------------|-------------------------|--------|--------|--------|-------|
| SANPS         | PI                      | 0.2253 | 0.0705 | 0      | 1.0082|
| SANPS         | PID                     | 4.6970 | 0.0909 | 3.4192 | 0.2154|
| SARPS         | PI                      | 0.2609 | 0.0753 | 0      | 0.4456|
| SARPS         | PID                     | 1.6215 | 0.1153 | 1.5082 | 0.0580|

Figure 8. Comparison with PI and PID controller for SANPS without GRC
Figure 9. Comparison with PI and PID controller for SARPS without GRC

Figure 10. Comparison with PI and PID controller for SANPS with GRC

Figure 11. Comparison with PI and PID controller for SARPS with GRC

7. Conclusion
The dynamic response of Figure 8 depicts that PID controller has less OS and ST as compared to the PI controller for a SANPS without GRC. The dynamic response of Figure 9 depicts that PID controller has less OS and ST as compared to the PI controller for a SARPS without GRC. Similarly, Figure 10 depicts that PID controller has less OS and ST as compared to the PI controller for a SANPS with GRC. Figure 11 depicts that PID controller has less OS and ST time as compared to the PI
controller for a SARPS with GRC. ST, overshoots, undershoots, oscillations are more in the time response of RPS compared to NPS. Also the ST, overshoots, undershoots, oscillations are more in the time response of RPS with GRC compared to RPS without GRC.

8. Appendices
Abbreviation of the terms used are given below
TG = speed governor time constant
Tt = turbine time constant
TPS = power system time constant
KPS = power system gain
ΔPg = incremental change in power generation
ΔPD = incremental change in load demand
ΔPC = incremental change in speed changer position
ΔF = deviation in frequency
R = speed regulation parameter
Kr = reheat coefficient
Tr = reheater time constant
BD: Block diagram
SARPS: Single area reheat power system
RPS: Reheat power system
SANPS: Single area non-reheat power system
OS: Overshoot
ST: Settling time
Simulation parameters : TPS = 20 sec, KPS = 120, TG = 0.08 sec, Tt = 0.3 sec, R = 2.4, Kr = 0.5, Tr = 10 sec

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