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IMPROVING STABILITY OF FOUR AREA POWER SYSTEM USING MODIFIED TUNING TECHNIQUE WITH GENETIC ALGORITHM

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ABSTRACT

This paper presents the improvement of the load frequency control (LFC) of multi area power system using PID controller and PID controller with PSS (PID-PSS Controllers). And compare the frequency response for a four area interconnected power system for both the controller model. In Automatic Generation Control (AGC), a small change in load demand may affect the system frequency; it would either increase or decrease. And variation in system frequency introduces a major effect on frequency dependent load. In this study a controller parameter can be adjusted along the system dynamic area via tuning itself through Genetic Algorithms (GA) optimization technique under Integral time weighted absolute value error (ITAE) Criterion. The simulation results for the proposed model, the frequency response are compared and the effects of both the controllers are shown over the effectiveness in the power system oscillations stabilization.

Keywords-Automatic Generation Control (AGC), Power System Stabilizer (PSS), Proportional Integral Derivative (PID), Genetic Algorithm (GA).

INTRODUCTION

In electrical power system, the primary objective of power system operation and control is to maintain continuous supply of power with an acceptable quality to all the consumers. The system will be in equilibrium, when there is a balance between the demand and the generation for any type of generation plant because mismatch between the generation and demand may create many adverse effects in the generated power. According to control theory point of view, the power system is a higher order nonlinear system and complex design operate in a constantly changing environment whose performance is influenced due to the number of devices with different response rates and operating characteristics. For the stable operating condition of a power system, the frequency should remain nearly constant or under desirable limit (maximum permissible change in frequency is ±0.5Hz) [16]. Under desirable limit of frequency, constancy of speed for frequency dependent load and an active power flow in a network, and more drop in frequency leads the reactive power flow in the power system. Usually a power system consist a number of generators and supplying power into the system are subjected to change in demands continuously. Active power demands are never constant and it varies regularly with the rising or falling nature. The strategy of controlling the active power demand for electric generators is known as automatic generation control (AGC).

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An interconnected area usually leads to improve the performance of a multi-area power system. The main advantageous of an interconnected power system is to regulate the system operation under stable condition and unstable conditions have to be corrected through multi area Automatic Generation Control (AGC). A multi area AGC system plays a key role in power system operation and control; and its goal is to steady the system frequency very close to a specified desirable limit and maintain power generation of individual units at the most economical operation with least tie line flow (power exchanged between each area) at their scheduled values with respect to during pre-fault condition. But also regain zero steady state error in frequency deviation when the system is subjected to small step load disturbance or fault at any point. In generation plant speed governor on each area generating unit's having the primary speed control, is design to be regulate load variation in steady state according to speed drop characteristics. While supplementary control technique originating at a central control centre allocates generation. In supplementary control during steady state, the generation is exactly matched with the load demand, and the tie line flow and frequency deviations is to be zero, is called area control error (ACE) vanishes in the steady state. Constancy of frequency and power interchanges between interconnected control areas at their scheduled values can be achieved by two primary objectives. These objectives are measuring control error signal (ACE), which represents the active power imbalance between generation and load, and is a linear combination of net power interchange and frequency deviations. Means overall performance of AGC in any power system depends on the proper design of both primary control loop (selection of R (regulation)) and secondary control loops (selection of gain for supplementary controller).

The conventional AGC depends upon control area parameter and it's not more efficient and reliable for modern power generation (distributed generation). Hence in AGC system, PID and PID-PSS controller is used to perform an input control signal with ACE. Both controller parameters of AGC system must be designed in such a way that it ensures safe, reliable and uninterrupted power supply. The PID and PID-PSS controller is used here to nullify the effect of load change and steady frequency and tie-line power deviations between the control areas. The most recent research trend for optimize the control area is the application of soft computing techniques such as neural networks, fuzzy logic, genetic algorithm (GA), PSO, BF etc. to tackle the difficulties associated with the design of regulators with higher order nonlinear models and insufficient knowledge about the system [7]. Since GA is the most popular and widely used algorithm over all the soft computing techniques. It is widely use to solve higher order nonlinear optimization problems in a number of engineering disciplines in general and particularly in the area of AGC power systems. GAs optimization technique is used to tune the control parameters of the PID and PID-PSS controller and regulate the area performance during abnormal condition.

II. Controller Model

a) PID Controller : PID controllers are control loop feedback technique type of controller usually for industrial control system causing easy in operation for industrial application. A simple structure and robust performance shows a wide range of operation over different industrial application. A PID controller aims to minimize the error between a measured dynamic system variable (process variable) and a reference (set point) of the controlled system, by calculating the error and generating a correction signal to the system from the error. A conventional PID controller having three constant parameters, the proportional term, the integral term and the derivative term, represented by P, I, and D respectively. Proportional term depends on the current error value, and its can be adjusted by multiplying the error by a constant Kp, called the proportional gain constant. In the integral control action the accumulation of past errors is multiplied by the integral gain Ki and added to the controller output, and Derivative part is a prediction of future errors,

$$\text{PID} = K_p + K_i/s + K_d s \qquad [1]$$

based on current rate of change and multiplying current rate of change by the derivative gain Kd.

Hence

the equation (1) is the ideal form of PID controller but it is impossible. There is no doubt that PID controller for

$$\frac{K_d}{1+T_d s}, \qquad T_d = 100 \qquad [2]$$

industries, because for an industrial application a low pass filter is used to omitting a high frequency noise in entry of differentiator. Therefore for a simulink model of PID controller, conversion function of differentiator is [12].

where $K_d \leq T_d$

a) **PID-PSS Controller:** The block diagram of a conventional PID-PSS controller is shown in the Figure 1. PID-PSS is cascade form of stabilizer gain block, a signal washout block and then the PID controller. The combination of pole placement and nonlinear programming techniques is considered to design the PSS with PID configuration (PSS-PID)

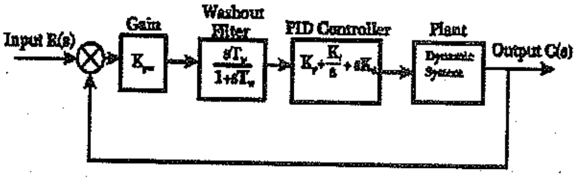

Figure 1. Block diagram of PSS

[2]. The PID-PSS parameters are tuned in a higher order nonlinear objective function with nonlinear constraints and solved by the optimization technique. The PID-PSS parameters are tuned in a higher order nonlinear objective function with nonlinear constraints and solved by the optimization technique.

These tuning techniques enhance the system performance using an extra controller parameter.

The stabilizer gain K_{pss} is used to find out the amount of damping introduced by stabilizer [24]. The signal washout block serves as high pass filter, with time constant T_w is high for allowing a signal associated to angular frequency ù$_r$ is passed without change and minimize the low frequency oscillation. T_W is the washout filter time constant. From the theoretical point of view the successful operation of washout function, the value of T_w lies between 1 to 20 sec [3]. In this work using a PID-PSS in place of PID, is to minimize the amount of change in frequency during transient condition under desirable range. Because during the transient condition (upto 1 sec) a frequency deviation is high and then it will reduced and this transient condition may affect the performance the frequency sensitive load.

III. MULTI - AREA AGC SYSTEM

This paper deals primarily with the realization of a four area AGC system and analysis the frequency response of the power system due to abnormal condition. In a four area system, four different control areas are interconnected through a six tie-line and the power interchange between each other through that tie line. In the four areas, AGC system the single control area is connected to another three areas as shown in Figure 2 and perform the schedule power interchange from that area to others areas.

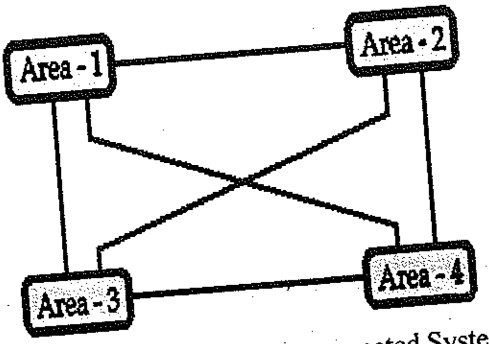

Figure 2. Four Area Interconnected System

In a multi area power system, the primary objective of the AGC system are to keep steady the control area frequency at nominal value and load sharing between generators proportional own rating and maintain the tie line flow at schedule value. When there is change in load demand or fault occurs in single area or more area of the power system then it may effect on the system performance usually in frequency. That will be overcome by the increase in generation in all the healthy areas associated with a change in the tie line power and a reduction in frequency. The frequency deviation in all areas severely affects the quality of frequency sensitive industries. But the normal operating state of the power system is that, each control area will be satisfied its own demand at a normal frequency and will absorb its own load changes. Hence interconnections establish increases the overall system reliability and overcome to this problem even if some generating units in any area is shut down. In the given proposed model, during disturbance the generating units in the other area are compensating to meet the load demand via three single control areas. So it is quite important to analyze the steady-state frequency deviation, tie-line flow deviation and generator outputs for an interconnected area after a load change occurs. In a four area system do not necessary the schedule power interchanges directly through the tie line connecting the respective areas. Actual flows cloud split over parallel paths through

$$\Delta P_{ij} = T_{ij}\,\Delta\delta_{ij} = \frac{2\pi}{s}T_{ij}\,(\Delta f_i - \Delta f_j) \quad [3]$$

Where, $\Delta\delta_{ij} = \Delta\delta_i - \Delta\delta_j$

δ_i, δ_j = equivalent power angle of voltage source (equivalent generating unit)

all the connecting areas, depending on the relative impedances of parallel paths and schedule interchange. The interchange schedule applicable to each area is the algebraic sum of power flows on all tie lines from that area to other areas [15].

The power transfer through the tie line between area i and j is given by

X_{ij} = tie line impedance between area i and area j

So the total tie line power exchange between areas 1 to other three areas can be calculated as

$$\Delta P_1 = \Delta P_{12} + \Delta P_{13} + \Delta P_{14}$$

$$\Delta P_1 = \frac{2\pi}{s}\sum_{j=2}^{4} T_{1j}\,(\Delta f_1 - \Delta f_j) \quad [4]$$

Similarly for n control areas, the total tie line power change between areas 1 to other (n-1) area is

$$\Delta P_i = \sum_{\substack{j=1\\ j\neq i}}^{n} \Delta P_{ij}$$

$$\Delta P_i = \frac{2\pi}{s}\sum_{\substack{j=2\\ j\neq i}}^{n}[T_{ij}\,(\Delta f_i - \Delta f_j)]$$

$$\Delta P_i = \frac{1}{s}\sum_{\substack{j=2\\ j\neq i}}^{n}[T_{ij}\,(\Delta\omega_i - \Delta\omega_j)] \quad [5]$$

For using a same value of synchronizing torque coefficient (T_{ij}) in all the tie line (for studying in given model $T_{ij} = 2$)

$$\text{Then}\quad \Delta P_i = \frac{1}{s}\sum_{\substack{j=2\\ j\neq i}}^{n}[2\,(\Delta\omega_i - \Delta\omega_j)]$$

$$\Delta P_i = \frac{2}{s}\sum_{\substack{j=2\\ j\neq i}}^{n}(\Delta\omega_i - \Delta\omega_j) \quad [6]$$

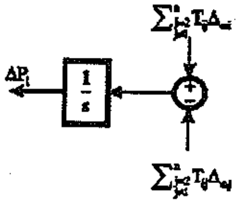

Fig.3 Tie line flows from i^{th} area to n area

The mathematical model of Multi-Area AGC system used for analysis is a four-area interconnected power system, where all areas without reheat steam turbine. There will be an area control error (ACE) for each area and it will try to reduce its own ACE to zero. The ACE of each area is the linear combination of the frequency deviation with bias factor and total tie line power deviation from one area to other three areas. Therefore ACEs considering for n area is given by,

$$ACEi = \sum_{\substack{j=1\\ j\neq i}}^{n}\Delta P_{ij} + B_i\Delta f \quad [7]$$

Where is the frequency bias constant

IV. OPTIMIZATION ALGORITHM

Genetic Algorithm (GA) is a probabilistic optimization technique with a high probability to finding a best solution in a given search space. It was developed by John Holland in 1970 [4]. In all the system on GA technique, is used to generate a population of required solutions for a given problem, using genetic operators inspired by natural genetic selection and natural variation. These genetic operators are selection, reproduction, crossover and mutation. Genetic Algorithm is used to solve a higher order problem having multiple variables of any domain. Its only requires the ability to develop a mathematical model of a set of input (the variables) according a model to finding an optimal solution. Essentially, the GA optimization technique that performs parallel, statistically and direct search to the fittest population of given fitness functions of multivariable problem. After the initializing process the fitness population, each string (individual) determines the performance of the string of new population. In that case the higher order string of a new population are mate each other is called crossover. During crossover a string having partial solutions combined each other. The algorithm gave a priority of fittest strings as parents, where better strings having more number of offspring. The GA explores the regions of the search space, because iteratively generations of reproduction and crossover produce more numbers of strings in those regions. Finally, mutations reproduce a small fraction of the strings.

Tuning of a PID and PID-PSS controller follows to the tuning of its various parameters (P, I, D, K_{pss} and T_w) to achieve an optimized value of the appropriate response. The basic output required for the system will be the stability, less rise time, less peak time and minimum overshoot. Different processes have different responses of these parameters which can be achieved by meaningful tuning of the controller parameters. If the system can be taken offline, the tuning method analyzed the step input response of the system; find out different PID and PID-PSS parameters. But in most of the industrial applications and control engineering, the system must be online and tuning process to be performed by experienced personnel and uncertainty always present due to human error. The objective function of any proposed model for any system is shown in figure 4. In this study the fitness function is in term of area control error (ACE) with "the integral of the time multiplied absolute value of the error" criterion (ITAE) is to be minimized. The fitness function for a proposed model of multi area is shown in equation (9).

In this paper, the error criterion considered is given by:

$$ITAE = \int_0^\infty t(e(t))\,dt \qquad [8]$$

The objective functions of four area interconnected system for ITAE criterion is, where the error signal is ACE for each area and for each area it will try to reduce zero. Hence

$$ITAE = \int_0^\infty t(ACE_i)\,dt \qquad [9]$$

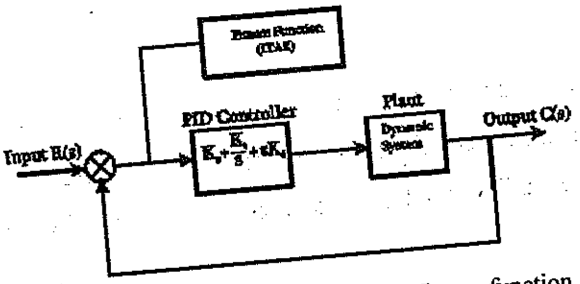

Figure 4 Block diagram of obtaining fitness function for GA

II SIMULINK MODEL AND RESULTS

An interconnected system comprising of four thermal areas power system has been used for simulation studies is shown in figure 5. Simulation model has been developed in MATLAB to obtain dynamic responses for various parameters for 0.1pu step load disturbance (decrease in load demand) in each area. The detailed block diagram of the system with all the parameters used in the model is shown in the simulink diagram. The optimum values of controller parameter have been found using ITAE criterion.

The PID and PID-PSS controller parameter value is shown below in table I and II. And comparing the both the tuned value we observe the amount of overshoot is reduced in the case of GA-PIDPSS as compare to GA-PID.

TABLE I : PARAMETERS FOR PID CONTROLLER

Parameter	Area 1	Area 2	Area 3	Area 4
K_d	6.733	4.152	8.413	6.374
K_i	1.062	8.026	3.777	9.837
K_p	6.037	4.695	9.024	8.937
Overshoot $\Delta\omega$	0.0012	0.0015	0.0022	0.0012

TABLE II PARAMETERS FOR PID-PSS CONTROLLER

Parameter	Area 1	Area 2	Area 3	Area 4
K_d	2.505	4.442	2.149	2.711
K_i	2.482	1.959	5.337	13.495
K_p	1.678	3.780	3.802	2.806
K_{pss}	4.177	4.149	5.192	5.482
T_w	8.271	2.716	3.781	14.210
Overshoot $\Delta\omega$	0.0068	0.0009	0.0012	0.0009

The frequency deviation for each area using both optimized value are shown below in respective plot.

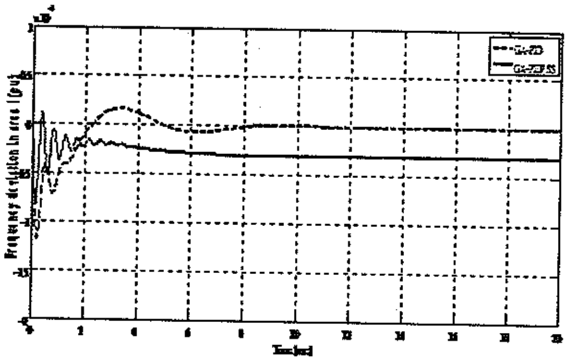

Figure. 6 Frequency deviation in area 1 for ITAE Criterion

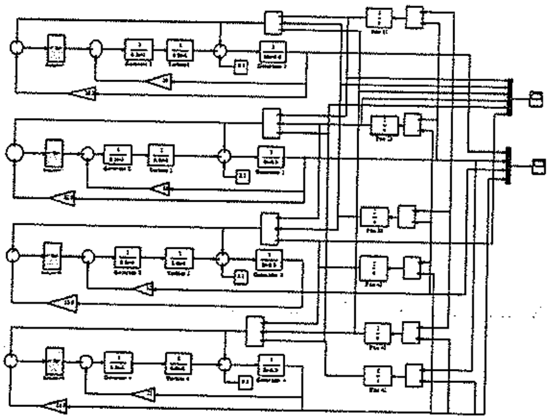

Figure.5 Simulink model of four area AGC system

Figure 6 shows the frequency deviation in area 1 using GA-PID, GA-PIDPSS for ITAE criterion, for a change in demand (decreases) 0.1pu for all areas. Where both the tuned controller restores the frequency at steady state in 10 sec. but the steady state frequency deviation is obtained in case of GA-PIDPSS is 0.0003pu

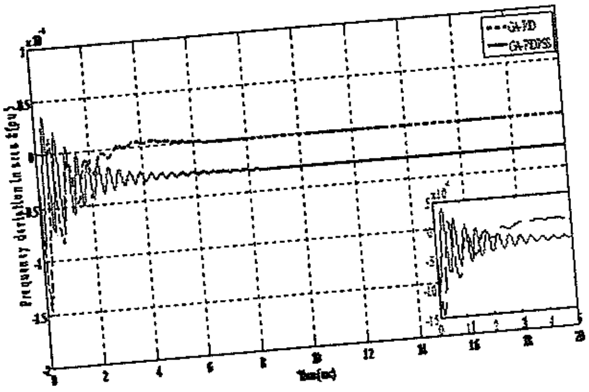

Figure. 7 Frequency deviation in area 2 for ITAE Criterion

Figure 7 shows the frequency deviation in area 2 using GA-PID, GA-PIDPSS for ITAE criterion, for a change in demand (decreases) 0.1pu for all areas. Where both the tuned controller restores the frequency at steady state in 10 sec. but the steady state frequency deviation is obtained in case of GA-PIDPSS is 0.0003pu.

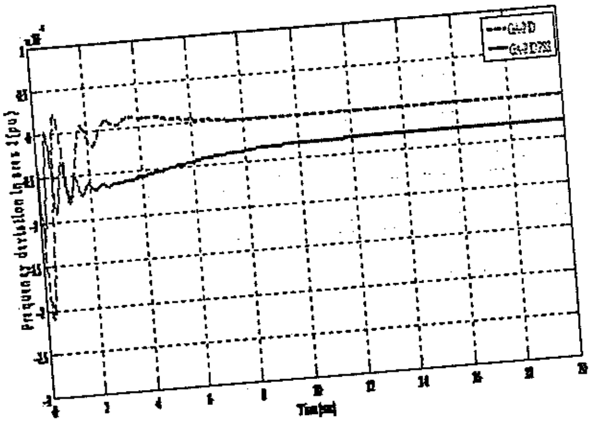

Figure 8 shows the frequency deviation in area 3 using GA-PID, GA-PIDPSS for ITAE criterion, for a change in demand (decreases) 0.1pu for all areas. Where both the tuned controller restores the frequency at steady state in 10 sec. but the steady state frequency deviation is obtained in case of GA-PIDPSS is 0.0003pu.

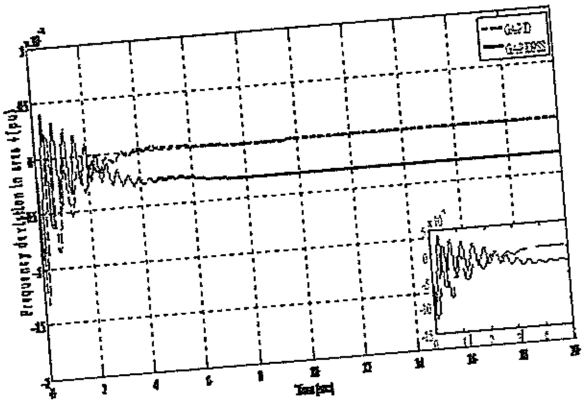

Figure. 9 Frequency deviation in area 4 for ITAE Criterion

Figure 9 shows the frequency deviation in area 4 using GA-PID, GA-PIDPSS for ITAE criterion, for a change in demand (decreases) 0.1pu for all areas. Where both the tuned controller restores the frequency at steady state in 10 sec. but the steady state frequency deviation is obtained in case of GA-PIDPSS is 0.0003pu.

CONCLUSION

A GA based tuned both controller gives fast response for four area power system. Studying the above the entire frequency response for entire four areas, GA-PID controller having no frequency deviation with respect to GA-PIDPSS controller. Both the tuned controller restores the frequency at steady state in 10 sec, using ITAE error criterion, but GA-PIDPSS controller cannot minimize the frequency deviation to zero. GA-PIDPSS controller shows that when demand is decreased then the frequency of the entire AGC system is increased. And in same case, GA-PID controller restores the frequency to pre-disturbance value. But when comparing the overshoot during transient a GA-PIDPSS controller minimize the peak overshoot with respect to GA-PID controller. The response via GA-PIDPSS can be much more improved if the lead-lag structure of PSS is used along with washout block and stabilizer gain block.

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