TIE LINE POWER CONTROL USING GENETIC ALGORITHM BASED LOAD FREQUENCY CONTROL CONTROLLER FOR A THREE AREA INTERCONNECTED SYSTEM

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Abstract

For stable operation of an interconnected power system Frequency the important parameter whose change should not vary largely. The control of both active power and frequency in a system is called as Load frequency control. If the frequency of the system is constant then the operation of power system is stable. But as the load changes on the system the frequency of the system changes. Hence we need to reduce these changes in frequency for ensuring the stability of the concerned system. There are various other conventional methods of tuning the controller for reducing the frequency changes but by using GENETIC ALGORITHM based tuning the frequency changes are reduced and the concerned system is brought into a stable mode in a less time when compared to the time taken in conventional methods.

Key Words : Load Frequency Control, Power System Stability, Genetic Algorithm

1. Introduction

Electrical Power systems convert the natural energy into electrical power. This electrical power is being transmitted from the generating stations to the consumer points through transmission lines. If we ensure the power quality that is being transferred we can optimize the operating performance of electrical instruments. We need to maintain a balance between active and reactive power between the generating station and consumer points. The above said balances give raise to new operating equilibrium points VOLTAGE and FREQUENCY. Equilibrium points will float when the above two balances are either changed or broken. However during power system operation the load on the system varies randomly and momentarily. For maintaining the balance of active and reactive power a control action is needed. As the load changes the two equilibrium points will change. Thus to keep this equilibrium points at standard values and to counter the random load changes and its effects a controller is needed.

The active and reactive power have their effect on frequency and voltage, so we will decouple the problem of controlling both voltage and frequency. The frequency change depends on the change in active power whereas the voltage change depends on the change in reactive power. We can classify the control problem into two problems which are independent of each other. One is the change in active power and frequency control while the second is the change in reactive power and voltage control.

McIlwaine [1], In a multi-area interconnected complex power system, frequency is maintained constant by load frequency control so that the tie line power is maintained at its scheduled value. If the load generation equilibrium is not maintained the frequency of the entire system changes. To maintain the nominal frequency, load shedding process will be initiated automatically. For a reliable system settling time and peak overshoot should be minimum.

Shayeghi [2], he proposed and categorised some design methods such as Classical methods, adaptive and robust control approaches, variable structure methods and intelligence based algorithms and digital control methods.

Wang [3], discussed the method which suits the practical application which takes uncertainties such as disturbances in the system. Such type of method will be robust, which is based on Riccati equation whose design will provide stable operation for all variations.

Bohn [4], he considered a trade-off between the system response and rate at which sampling is done in digital control method because the controller's nature is discrete.

Yazdizadeh [5], proposed some methods based on intelligence which tunes the controller by evaluating the cost and fitness function. The PID controllers are commonly used because of their simplicity and effectiveness.

Killingsworth NJ [6], In this paper selection of controller gain is done without the system parameter knowledge. Here he used some PID controller performance indices such as Absolute Integral Error, Square of Integral Error, etc.

Pothiya [7], Proposed a PID controller for LFC based on fuzzy logic. For tuning the PID gains a multiple tabu search was utilized.
2. Power System Modelling

Here we will model the power system using the first order three simple transfer functions. The transfer functions of generator, turbine and power system is modelled by simple first order systems. The inputs to the system thus formed are the changes in load. The power flowing through the tie-line and frequency of that power in the area are being monitored by its own area control. Area Control Error (ACE) is the linear combination of both frequency errors and tie-line errors. ACE thus computed is given as input to its controller. The resultant control action thus produced or a part of it will be applied to the turbine-governor unit.

1. Block Diagram Of Interconnected System: Now the power system which are interconnected by tie-lines will be divided into different load frequency control areas. Here in this paper we will take three areas interconnected by six tie-line as shown in Fig.1 with the assumption that each control area will be represented by a governor, turbine-generator.

![Fig. 1 : Block diagram of three area interconnected model](image)

2. Turbines: A turbine basically transforms the energy from moving steam or kinetic energy of moving water, into mechanical energy. Thus the mechanical energy generated will be used for driving the generator. In LFC models we have three kinds turbines (i) reheat type, (ii) non-reheat and (iii) hydraulic turbines, all of them will be represented by using equivalent transfer function for our analysis.

The non-reheat turbines is represented by simple transfer function as shown below

\[ G_{rs}(s) = \frac{\delta P_m(s)}{\delta P_v(s)} = \frac{1}{T_{ch}s + 1} \]  

(1)

Where \( \delta P_v(s) \) is the change in position of valve/gate.

Reheat type turbines are modelled by using second-order units as shown in Eq.2. Because of high and low steam pressure they will have different stages. The transfer function is as shown below

\[ G_{rs}(s) = \frac{\delta P_m(s)}{\delta P_v(s)} = \frac{P_{hp}T_{rh}s + 1}{(T_{ch}s + 1)(T_{rh}s + 1)} \]  

(2)

Where \( T_{rh} \) stands represents the reheat time of low pressure whereas \( F_{hp} \) represents the high pressure stage rating.

3) GENERATORS: Generator units in a power system are used to convert the mechanical energy which they receive from turbines into electrical energy. But for LFC rate of driving the rotor that is the rotor speed which determines the frequency of the power systems instead of energy transformation. Whenever there is a change in load there will be a disturbance in the balance between the electrical energy output from generator and the mechanical energy supplied. This disturbance generates a change in the rotor speed which results in changes in speed \( \omega_r \), which will be converted into frequency deviations \( \omega_f \). Now a relationship is established between \( \omega_m \) and \( \omega_f \) is shown in Fig.2 where \( M \) will be the inertia constant of generator.

![Fig. 2 : Generator block diagram](image)

The power loads such as resistive loads constant irrespective of changes in frequency i.e., rotor speed, and motor loads which change. If the mechanical input to the generator remain constant irrespective of the motors loads then the changes in rotor speed i.e., different from scheduled value is made zero. it is shown in Fig.3 here \( D \) is the constant of load damping.

![Fig. 3 : Generator block diagram with load damping effect](image)
4) **Governors**: Governors are used to sense the changes in frequency i.e., because of load changes and reduce it by properly changing the input to the turbine. The schematic depiction of a speed governor unit is shown in Fig.4, where \( R \) is the regulation characteristic of speed and \( T_g \) is the constant of the governor. As the load changes in the system the frequency of the system changes. The main aim of LFC unit is to regulate the changes in frequency with respect to the changes in active power in the system. Also the load reference will be set for adjusting the valve/gate positions so that the changes because of load are reduced rather minimized by the change in power generation rather than frequency deviation.

5) **The Interconnected Power Systems**: Tie- Lines

In modern day power systems are interconnected with one other by means of tie-lines. Whenever the frequencies of the interconnected areas are changed, there will be power transfer in the tie-line which connects them. The tie-lines are modelled and the Laplace representation of the block diagram in Fig.5 is given by

\[
ACE_a = \sum_{b=1, a \neq b} \Delta P_{tie-ab} + B_a \Delta f_a \tag{4}
\]

Where \( B_a \) represents the frequency response characteristic for area a and

\[
B_a = D_a + \frac{1}{R_a} \tag{5}
\]

### 3. Design of Controller

#### A. Conventional Methods

In industries mostly Proportional-integral-derivative (PID) controllers are used since they are simple, number of parameters tuned and easy to tune. But also they provide acceptable performances for large range processes. PID controllers are particularly used for process whose dynamics are modelled by first or second order system.

Among the available methods of tuning PID controllers the popular tuning method is Ziegler-Nichols method. The controller parameters are calculated based on step response of the plant. The parameters obtained from step response are time delay (T) and time lag (a).

1) **Ziegler Nichols Method**: 1. The gain parameter K will be calculated at low frequencies and will be given as ratio of output level to input level.

2. The inverse of the frequency \( Fu \) where the phase crosses -180 degrees gives the period of oscillation, \( tu \).

3. The inverse of the plant gain \( K_c \) occurring at critical oscillation frequency \( Fu \) gives us the gain margin \( Ku \).

4. Apply the frequency \( Fu \) to the plant first order lag terms to solve for the model’s a term.

\[
a = \sqrt{K^2 K_u^2 - (4\pi F_u^2)}
\]

5. Next obtain the phase shift of the lag stage by substituting \( Fu \) into the first-order lag model.
The rest of 180 degrees phase shift is assigned to the pure time delay term.

\[ T = \frac{(-\pi - \phi)}{2\pi F_u} \]

A. Genetic Algorithm

Genetic Algorithm, inspired by biological principles, are natural selection process and mechanics of natural genetics. They are search and optimization techniques. They manipulate a collection of potential solutions whereas conventional methods manipulate just one potential solution. The collection of potential solutions is known as population. The chromosomes are solutions, these are the encoded representation of controller parameters. Fitness of each chromosome is evaluated and compared with other chromosomes, the fitness of higher value and the corresponding chromosome will be our solution. For better encoding the solutions, GA will use the genetic operators or evaluation operators. Cross over and mutation are used for forming new set of chromosomes from already existing ones. The selection of parent chromosome is based on fitness function. Higher the value of fitness corresponding chromosome will be selected as parent chromosome.

Table 1
Change in Frequency without Controller

| Area   | Peak Overshoot | Settling Time(s) |
|--------|----------------|-----------------|
| Area-1 | -0.01293       | 14              |
| Area-2 | -0.01804       | 14              |
| Area-3 | -0.01715       | 12              |

for cross over and mutation. The offspring is generated by modifying the parent chromosome.

We will initiate the genetic algorithm with an initial population of 20-100 individuals. This set is defined as mating pool which is shown by a real number or a binary string called a chromosome. We will form an objective function which will be minimized to get the desired parameters. The Objective function is evaluated to find its fitness. The fitness of each chromosome is obtained and by using the nature's survival of fittest strategy is applied.

4. Results

The comparison of deviation in frequency, Area Control Error and tie-line power changes of a two area interconnected reheat thermal power system without controller, with Conventional PID controller, with GA based PID controller are shown below.
5. Conclusion

In this work we implemented the genetic algorithm for optimizing the PID controller parameters for LFC. We can see how the frequency gets varied wrt to the load changes, the changes in tie-line power, frequency deviations along with the area control error in the system when no control is applied, when controller by conventional tuning is used and when GA based method is used. We can now compare the peak over shoots and settling time for the above said. Here the main motive was to minimise both the settling time and maximum overshoot.

Table 2
Change in Frequency with Controller Tuned by Ziegler Nichols Method

| Area | Peak Overshoot | Settling Time(s) |
|------|----------------|------------------|
| Area-1 | -0.00682 | 10.19 |
| Area-2 | -0.01139 | 10.19 |
| Area-3 | -0.009481 | 10.2 |

By using conventional methods for tuning the parameters we have seen that the peak over shoot and settling time are reduced when compared to the response of the system without controller.

Table 3
Change in Frequency with Controller Tuned by Genetic Algorithm

| Area | Peak Overshoot | Settling Time(s) |
|------|----------------|------------------|
| Area-1 | -0.001726 | 3.053 |
| Area-2 | 0.0004216 | 3.719 |
| Area-3 | -0.00177 | 4.461 |

Table 4
Tie-line Power Variation without Controller

| Tie-line | Peak Overshoot | Settling Time(s) |
|----------|----------------|------------------|
| T_{12}  | -0.0108 | 10 |
| T_{13}  | 0.00877 | 12.25 |
| T_{21}  | 0.0108 | 10 |
| T_{23}  | -0.01352 | 10.25 |
| T_{31}  | -0.00877 | 12.25 |
| T_{32}  | 0.01352 | 10.25 |

Table 5
Tie-line Power Variation with Controller Tuned by Ziegler Nichols Method

| Tie-line | Peak Overshoot | Settling Time(s) |
|----------|----------------|------------------|
| T_{12}  | -0.006583 | 6.5 |
| T_{13}  | 0.004547 | 7.538 |
| T_{21}  | 0.006557 | 6.5 |
| T_{23}  | 0.008549 | 7.53 |
| T_{31}  | -0.004547 | 7.538 |
| T_{32}  | -0.008549 | 7.53 |

Table 6
Tie-line Power Variation with Controller Tuned by Genetic Algorithm

| Tie-line | Peak Overshoot | Settling Time(s) |
|----------|----------------|------------------|
| T_{12}  | -0.001763 | 5.21 |
| T_{13}  | 0.00018 | 5.61 |
| T_{21}  | 0.001745 | 5.21 |
| T_{23}  | 0.1666 | 5.6 |
| T_{31}  | -0.00018 | 5.61 |
| T_{32}  | -0.1666 | 5.6 |
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