Application Of Evolutionary Programming To Load Frequency Control In Power System With HVDC Link

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***Abstract* - : In an interconnected power system, as a power load demand varies randomly, both area frequency and tie-line power interchange also vary. The objectives of load frequency control (LFC) are to minimize the transient deviations in these variables (area frequency and tie-line power interchange) and to ensure their steady state errors to be zero. When dealing with the LFC problem of power systems, unexpected external disturbances, parameter uncertainties and the model uncertainties of the power system pose big challenges for controller design. The controller is constructed for a two-area power system with different turbine units including non-reheat and reheat and in different areas with AC–DC parallel tie-lines. The dynamic model of the power system and the controller design based on the model are elaborated in this project. This work examines the effect of Generation rate constraints and Dead band in a Two-area interconnected system consisting of thermal generation units provided with conventional proportional and integral controllers. Separate studies were made for each case and results are compared.**

***Keywords*: :** Load frequency control, PI controller, Evolutionary Programming, AC/DC tie lines.

I. .Introduction

Power systems are used to convert natural energy into electric power. They transport electricity to factories and houses to satisfy all kinds of power needs. To optimize the performance of electrical equipment, it is important to ensure the quality of the electric power. It is well known that three-phase alternating current (AC) is generally used to transport the electricity. During the transportation, both the active power balance and the reactive power balance must be maintained between generating and utilizing the AC power. Those two balances correspond to two equilibrium points: Frequency and Voltage. When either of the two balances is broken and reset at a new level, the equilibrium points will float. A good quality of the electric power system requires both the frequency and voltage to remain at standard values during operation. For North America, the standard values for the frequency and voltage are 60HZ and 120Volts respectively. However, the users of the electric power change the loads randomly and momentarily. It will be impossible to maintain the balances of both the active and reactive powers without control. As a result of the imbalance, the frequency and voltage levels will be varying with the change of the loads. Thus, a control system is essential to cancel the effects of the random load changes and to keep the frequency and voltage at the standard values.

Although the active power and reactive power have the combined effects on the frequency and voltage, the control problem of the frequency and voltage can be decoupled. The frequency is highly dependent on the active power while the voltage is highly dependent on the reactive power. Thus, the control issue in power systems can be decoupled into two independent problems. One is about the active power and frequency control while the other is about the reactive power and voltage control. The active power and frequency control is referred to as load frequency control (LFC).

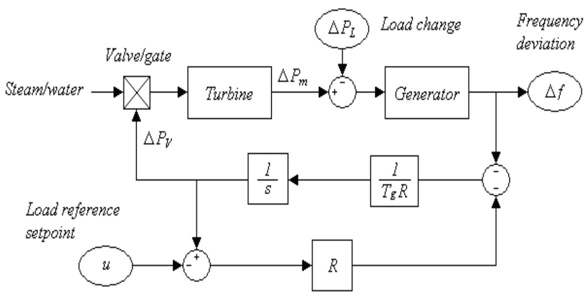
The foremost task of LFC is to keep the frequency constant against the randomly varying active power loads, which are also referred to as unknown external disturbance. Another task of the LFC is to regulate the tie-line power exchange error. A typical large-scale power system is composed of several areas of generating units. In order to enhance the fault tolerance of the entire power system, these generating units are connected via tie-lines. The usage of tie-line power imports a new error into the control system, i.e., tie-line power exchange error. When a sudden active power load change occurs to an area, the area will obtain energy via tie-lines from other areas. But eventually, the area that is subject to the load change should balance it without external support. Otherwise there would be economic conflicts between the areas. Hence, each area requires a separate load frequency controller to regulate the tie-line power exchange error so that all the areas in an interconnected power system can set their set points differently. Another problem is that the interconnection of the power systems results in huge increase in both the order of the system and the number of the tuning controller parameters. As a result, when modeling such complex higher order power systems, the model and parameter approximations cannot be avoided. Therefore, the requirement of the LFC is to be robust against the uncertainties of the system model and the variations of systems parameters in reality.

In summary the LFC has two major assignments, which are to be maintained the standard value of frequency and to keep the tie line power exchange under schedule in the presence of any load changes. In addition, the LFC has to be robust against unknown external disturbance and system model and parameter uncertainties. The higher order interconnected power system could also increase the complexities of the controller design of the LFC.

II. MODELLING OF TWO AREA POWER SYSTEM

Speed governing system:

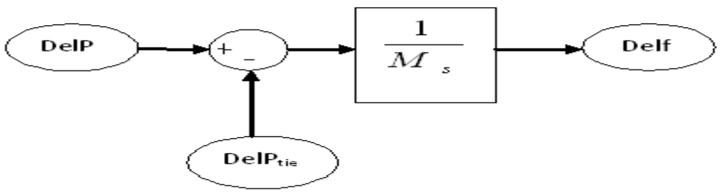
Governors are the units that are used in power systems to sense the frequency bias caused by the load change and cancel it by varying the inputs of the turbines. The schematic diagram of a speed governing unit is shown in Figure, where R is the speed regulation characteristic and T_g is the time



time constant of the governor. If without load reference, when the load change occurs, part of the change will be compensated by the valve/gate adjustment while the rest of the change is represented in the form of frequency deviation. The goal of LFC is to regulate frequency deviation in the presence of varying active power load. Thus, the load reference set point can be used to adjust the valve/gate positions so that all the load change is canceled by the power generation rather than resulting in a frequency deviation.

Generator:

A generator unit in power systems converts the mechanical power received from the turbine into electrical power. But for LFC, we focus on the rotor speed output (frequency of the power systems) of the generator instead of the energy transformation. Since electrical power is hard to store in large amounts, the balance has to be maintained between the generated power and the load demand.



Turbine:

Non-reheat turbines are first-order units. A time delay (denoted by T_{ch}) occurs between switching the valve and producing the turbine torque. The transfer function of the non-reheat turbine is represented as

$$G_{NR}(S) = \frac{\Delta P_m(S)}{\Delta P_v(S)} = \frac{1}{T_{ch}S+1}$$

Where ΔP_v is the valve/gate position change. Reheat turbines are modeled as second-order units, since they have different stages due to high and low steam pressure. The transfer function can be represented as

$$G_R(S) = \frac{\Delta P_m(S)}{\Delta P_v(S)} = \frac{F_{hp}T_{rh}S+1}{(T_{ch}S+1)(T_{rh}S+1)}$$

Where T_{rh} stands for the low pressure reheat time and F_{hp} represents the high pressure stage rating.

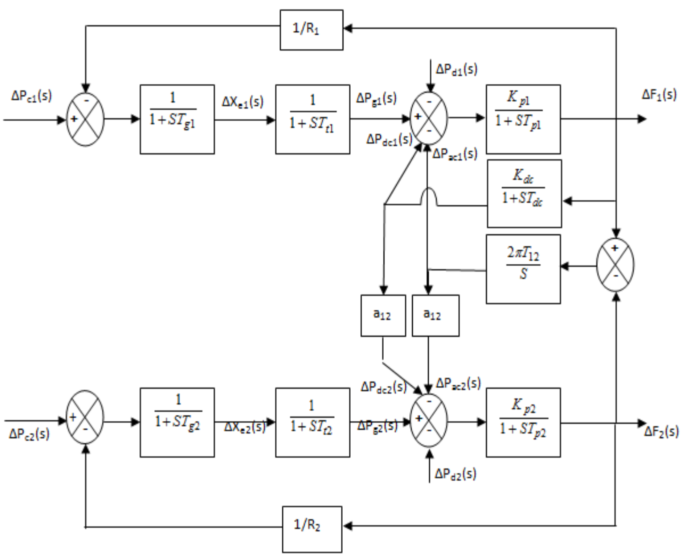


Fig.1.Block diagram of two area interconnected non-reheat thermal power system with AC and DC tie lines.

III. PI CONTROLLER AND EVOLUTIONARY PROGRAMMING

PI controller:

By using the control strategy we obtain an overall system that will meet the performance specifications. We have added to the primary ALFC loop so called integral control: i.e., we let the speed changer be commended by a signal obtained by first amplifying and then integrating the frequency error,

$$\Delta P^{ref} = -k_i \int \Delta f \, dt$$

The unit for k_i is per-unit mega watt per hertz and sec. A

PI controller designed on a two area inter connected power plant is presented where the controllers parameters of the PI controller are tuned using trial and error approach.

Generation Rate Constraints:

In power systems having steam plants,power generation can change only at a specified maximum rate.Most of the reheat units have a generation rate around 3%/min and some have generation rate between 5 to 10%/min.When GRC is considered ,the system dynamic model becomes non linear and linear control techniques cannot be applied for the optimization of the controller setting. The GRC for both the areas is considered by adding limiters to the governors. Two limiters bounded by +0.0005 are used.

Governor Dead Band :

The governor dead band is defined as the total magnitude of sustained speed change within which there is no change in valve position.The limiting value of the dead band is 0.06%. In the presence of GRC and dead band even for small load perturbation ,the system becomes highly non-linear and hence the optimization problem rather becomes complex.

EvolutionaryProgramming:

Classical evolutionary programming is implemented as follows:

1. Generate the initial population of μ individuals,and set k=1.Each individual is taken as a pair of real valued vectors,(x_i,η_i),where x_i's are objective variables and η_i's are standard deviation for Gaussian mutations (also known as strategy parameters in self adaptive evolutionary algorithms).
2. Evaluate the fitness score for each individual (x_i,η_i),for all i ϵ {1,…μ},of the population based on the objective function ,$f(x_i)$.
3. Each parent (x_i,η_i),i=1,….μ,creates a single offspring (x_i^1,η_i^1) by :for j=1,…n,

$$x_i^1(j) = x_i(j)+\eta_i(j)N_j(0,1),$$

$$\eta_i^1(j) = \eta_i(j)\exp(r^1 N(0,1)+rN_j(0,1))$$

The factors r and r^1 are commonly set to $(\sqrt{2\sqrt{n}})^{-1}$ and $(\sqrt{2n})^{-1}$.

4. Calculate the fitness of each offspring (x_i^1,η_i^1),for all i ϵ {1,….μ}.
5. Conduct pairwise comparison over the union of parents (x_i,η_i), and offspring (x_i^1,η_i^1),for all i ϵ {1,….μ}.For each individual ,q opponents are chosen uniformly at random from all the parents and offspring.For each comparison,if the individual's fitness is no smaller than the opponent's ,it receives a "win".
6. Select the μ individuals out of (x_i,η_i) and (x_i^1,η_i^1) for all i ϵ {1,….μ},that have the most wins to be parents of the next generation.
7. Stop if the halting criterion is satisfied ;otherwise ,k=k+1 and go to step 3.

IV. SIMULATION RESULTS

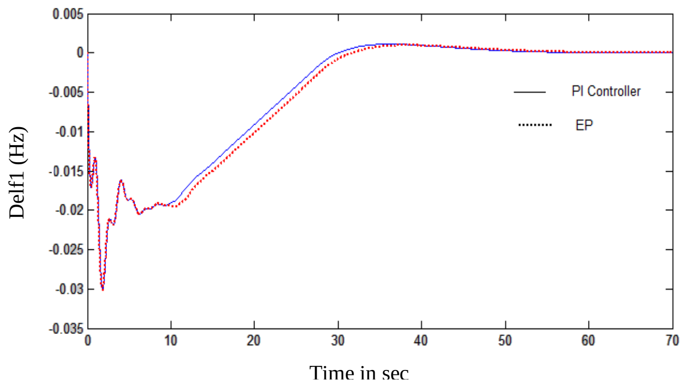


Fig.2. Frequency deviation in area 1 for 0.01 p.u MW step load change in area 1

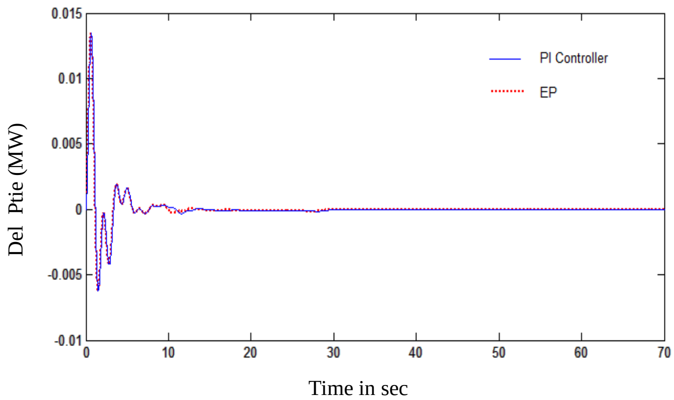


Fig.3.Tieline power deviations of area 1 for 0.01 p.u MW step load change in area 2

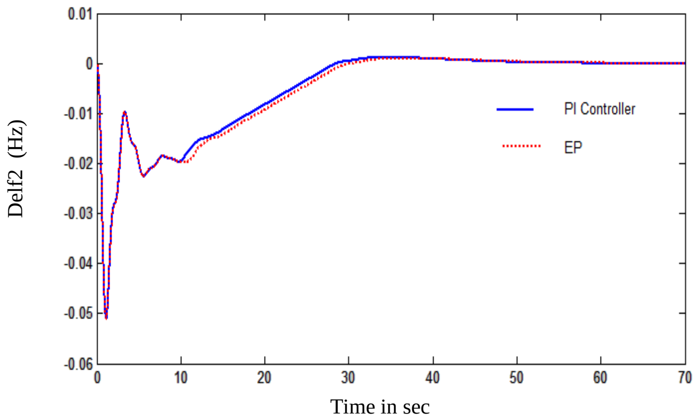


Fig.4. Frequency deviation in area 2 for 0.01p.u MW step load change in area 1

V. CONCLUSION

Models of inter connected power system having different area characteristics have been developed for both Proportional integral control strategies and Evolutionary Programming techniques. The models have also been tested for system stability before and after applying closed loop feedback control.Generation rate constraints and Dead band are implemented in this interconnected power system. Evolutionary programming technique is found to be advantageous than other conventional techniques since it minimizes the transient deviations in area frequency and tie line power interchange and steady state error is zero.

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