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LOAD FREQUENCY CONTROL OF A TWO AREA RESTRUCTURED HYBRID POWER SYSTEM USING GA TUNED PID CONTROLLER

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Abstract : — In recent years the power scenario has gone through a major overhaul with the deregulation of electricity market and introduction of renewable sources into the system. Load frequency control (LFC) is one of the important ancillary services present in the power system. This work represents a load frequency control scheme for an interconnected two area hybrid system in restructured power system. Proposed scheme utilizes a classical Proportional-Integral-Derivative (PID) controller whose gain parameters Kp, Ki, Kd are tuned by Integral Square Error (ISE) control strategy using Genetic Algorithm (GA). In this work MATLAB/SIMULINK is used as a simulation tool.

Keywords— Load frequency control, Power system restructuring, Genetic algorithm, Hybrid power system

I. INTRODUCTION

In any electrical power system variation in load demand causes variation in frequency and tie line power. The problem becomes more severe in a renewable source integrated system due to intermittency associated with the renewable energy sources. Load frequency control (LFC) is one of the important ancillary services present in the power system whose primary objective is to minimize these transient deviations in frequency and tie-line power and to make their steady state errors to be zero. However, with the introduction of deregulated electricity market and hybrid energy systems LFC scheme should also be modified to accommodate different type of transactions like Poolco based transactions, bilateral transactions or a combination of both and different resources[1].

A lot of research work has been done in recent years pertaining to LFC in both traditional and deregulated environment. Several researchers proposed different control strategies for design of LFC with better dynamic characteristics. PID controller has also found many successful applications in load frequency control in power system. A PID load frequency controller was proposed by Padhan et al. for a multi area power system in which gain of controllers were determined by expanding controller transfer function using Laurent series [2]. For estimation of power system dynamics a relay based identification technique was adopted. From the obtained results it was observed that performance of the controller was quite satisfactory even in the presence of plant parameter uncertainties. Another PID control design based on maximum peak resonance specification backed by Nichol's chart was presented for a multi-machine system [3]. In order to make the control design effective to manage overshoot, stability and dynamics of the system the open loop frequency curve was made tangent to a specified ellipse. The very similar control design was also successfully implemented for a multi-machine hydropower system [4]. In [5] a PID control design whose gain parameters were optimized by a multi-objective Non-dominated sorting genetic algorithm-II was proposed for an inter-connected power system. An additional filter was used with the derivative term to minimize the noise.

This work represents a load frequency control scheme for a two area interconnected restructured hybrid power systems. Proposed load frequency control scheme utilizes a classical Proportional-Integral-Derivative (PID) controller in each area for controlling load frequency. For optimal performance of the proposed control scheme gain parameters of PID controller Kp, Ki, Kd have been tuned. Integral Square Error (ISE) of the system is used as performance index and Genetic Algorithm (GA) is used for optimization of parameters. In this work MATLAB/SIMULINK platform is used to develop test system models.

RESTRUCTURED POWER SYSTEM

In a restructured power system the vertical utility structure of the traditional power system is disintegrated and three different types of utilities namely Generations companies (GENCOs), Distribution companies (DISCOs) and Transmission companies (TRANSCOs) takes care of generation, distribution and transmission respectively. A DISCO buys energy from any GENCO according to its convenience and provides it to consumers while a TRANSCO facilitates the transmission of energy from the GENCO to the DISCO. In every area there are multiple GENCOs, DISCOs and consumers are free to buy energy from any DISCO. Like other industries in this competitive environment, it is expected that the electricity power restructuring will reduce the cost of power charged to small businesses and consumers, and reduce the cost of electricity generation [6-8].

SYSTEM DESCRIPTION

The hybrid test system represented in this work comprises of two equal areas; in each area there are three GENCOs and two DISCOs. GENCOs of area 1 consists of one thermal, one hydro and one solar unit whereas area2 consists of one thermal, one hydro and one wind unit. Schematic diagram of this test system is given in Fig.1. The wind turbine generator used in the system is a doubly fed induction generator which can be made to participate in LFC by using kinetic energy stored in its rotor. A battery is also connected with solar generating system in order to store the excess energy during surplus period and to provide required energy during deficiency. In addition to supplying power to DISCOs of its own area, each area provides required power to other areas as contracted. Areas are interconnected by tie-lines.

The generalized formula for scheduled steady state power flow deviation on the tie-line connecting area 1 and area 2 of a two area test system can be given as:

$$\Delta P_{tie\ 1-2} scheduled = \begin{pmatrix} Demand\ of\ DISCOs\ in\ area\ 2 \\ from\ GENCOs\ in\ area\ 1 \end{pmatrix} - \begin{pmatrix} Demand\ of\ DISCOs\ in\ area\ 1 \\ from\ GENCOs\ in\ area\ 2 \end{pmatrix} \quad (1)$$

Now actual power flow deviation in tie-line 1-2 can be calculated from:

$$\Delta P_{tie\ 1-2} actual = \left(2\pi . \frac{T_{12}}{s}\right) . (\Delta f_1 - \Delta f_2) \quad (2)$$

In any given time, the error in tie-line power deviation $\Delta P_{tie\ 1-2} error$ is given as:

$$\Delta P_{tie\ 1-2} error = \Delta P_{tie\ 1-2} actual - \Delta P_{tie\ 1-2} schedule \quad (3)$$

This error in tie-line power deviation and frequency deviation is used to generate area control error (ACE) signal. Expressions for ACE signals of given test system can be written as [5]:

For area-1:

$$ACE_1 = B_1 \Delta f_1 + \Delta P_{tie\ 1-2} error \quad (4)$$

For area-2:

$$ACE_2 = B_2 \Delta f_2 + \Delta P_{tie\ 2-1} error \quad (5)$$

In the present work integral square error (ISE) is used as objective function for tuning of gain parameters. For this hybrid test system expression for ISE becomes

$$ISE = \int_0^{\infty} ((\mathrm{ACE}_1)^2 + (\mathrm{ACE}_2)^2) dt \quad (6)$$

The Simulink model of the hybrid test system with different components is shown in Fig. 2. As the PID controller is an important component, so its tuning is important. Here GA is used to find the optimized values of parameters.

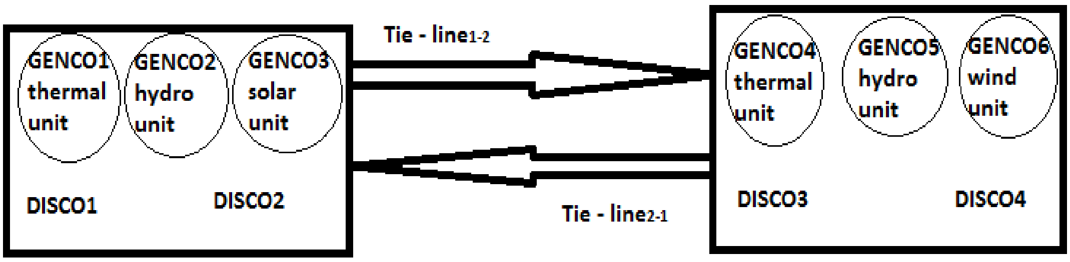

Fig. 1 Schematic diagram of hybrid test system

GENETIC ALGORITHM

Genetic algorithm is inspired by Charles Darwin's theory of survival of fittest and imitates biological processes such as inheritance, mutation, selection and crossover for finding global optimum of complex optimization problem [95]. Genetic algorithm initiates with a set of feasible solution termed as population. In genetic algorithm terminology each solution in population is known as chromosome. A new set of population is created from current set by applying genetic operators such as crossover and mutation to current set of population. Generally, chromosomes having relatively higher fitness in population are chosen to formulate new solutions. Fitness of new set of solutions thus generated is expected to be better than that of previous set. The four basic steps of implementation of GA are: encoding of solutions, reproduction, crossover and mutation [9-12]. The flowchart for execution of GA is shown in Fig. 2.

For optimization in GA each solution is represented by a string of 30 bits (each controller gain by 5 bits). Fitness value of each chromosome is determined by evaluating the integral square error of the system. Roulette wheel selection method is used to select chromosomes for crossover operation and two point crossover is performed. Mutation operator is sparsely applied on produced offsprings. Chromosomes having high value of fitness from parents and newly produced offsprings moves to next generation while others get destroyed.

RESULT AND ANALYSIS

The soft computing technique implemented for tuning of gain parameters of PID controller is genetic algorithm. Optimized PID gain parameters obtained by this soft computing technique are presented in Table 1. Optimized value of ITSE for the system stands at 0.0000214. Frequency responses of both areas of the hybrid system corresponding to the obtained set of tuned parameters are plotted in Fig. 3, Fig. 4., while tie-line power characteristic of the system is presented in Fig. 5.

Table 1: Optimized gains for hybrid test system with 20% renewable penetration using GA.

Area-1	K_p	3.322546
	K_i	4.250991
	K_d	3.74979
Area-2	K_p	4.824443
	K_i	2.621805
	K_d	4.566076
ITSE		0.0000214

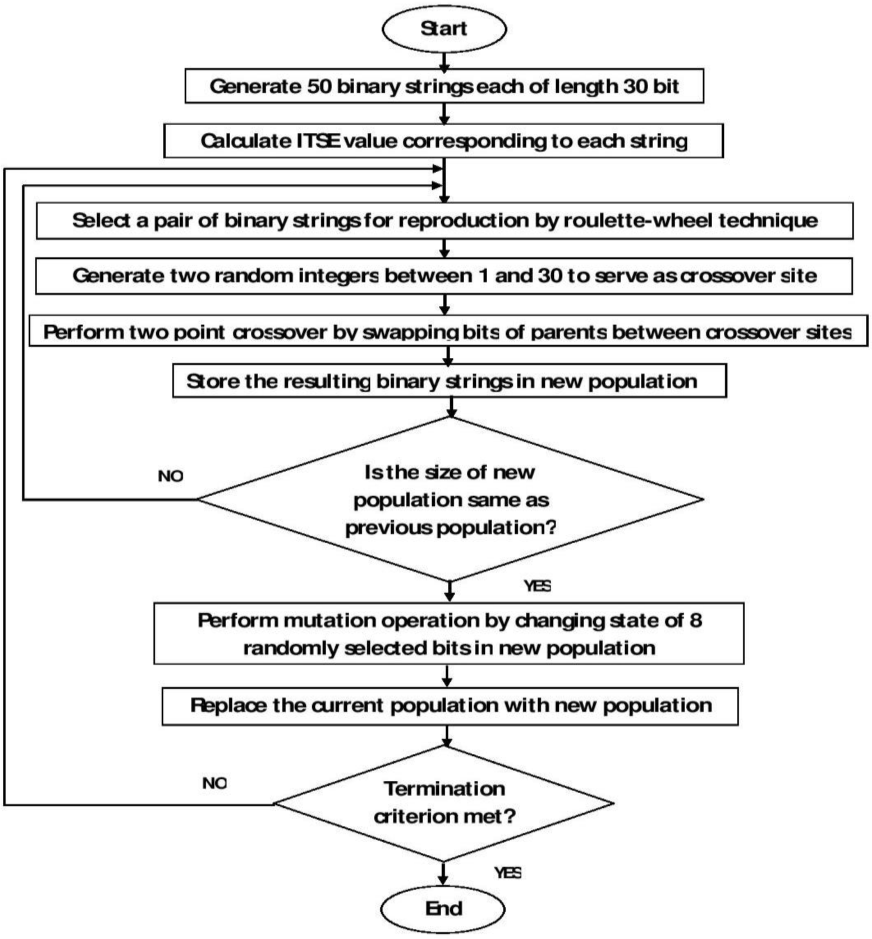

Fig. 2 Flowchart of Genetic Algorithm

In this case, area-1 is exposed to a maximum frequency fluctuation of 0.001235pu while area-2 is subjected to 0.001409pu. This is expected due to the slow response of wind generating system. Maximum stress on tie-line connecting two areas is found to be 0.000923. Incremental generations from different GENCOs present in two areas are plotted in Fig. 6 and Fig. 7 respectively.

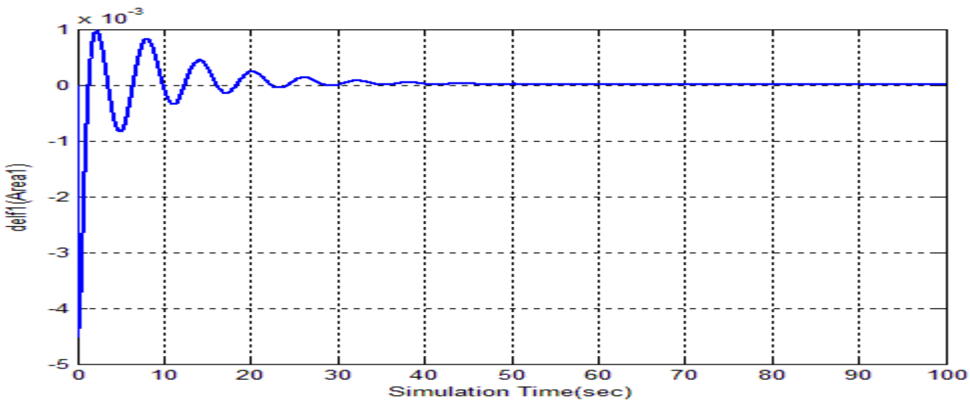

Fig. 3 Frequency deviation of area-1 for hybrid test system with 20% renewable penetration using GA.

The total incremental generation from area 1 comes out to be 0.0205pu (Thermal-0.00951pu, Hydro- 0.00699pu, Bat-0.00400pu) while in area 2 it is 0.0195pu (Thermal-0.00901pu, Hydro- 0.006486pu, Wind-0.00404pu). So some of total incremental generations from both areas match total incremental demand from all DISCOs.

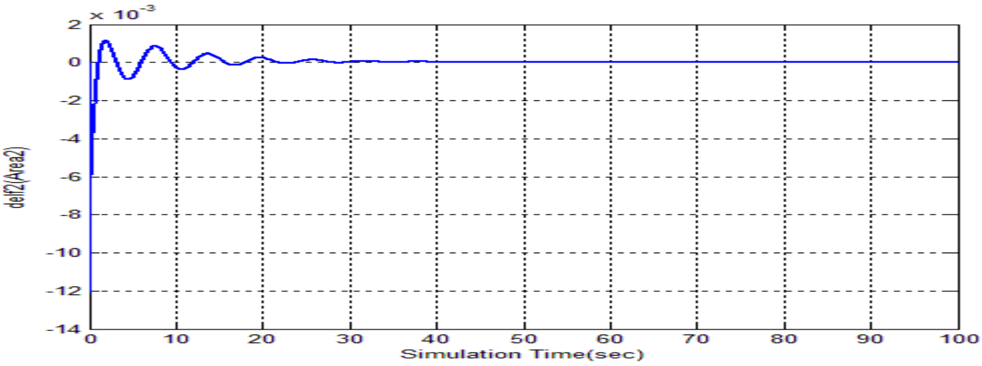

Fig. 4 Frequency deviation of area-2 for hybrid test system with 20% renewable penetration using GA.

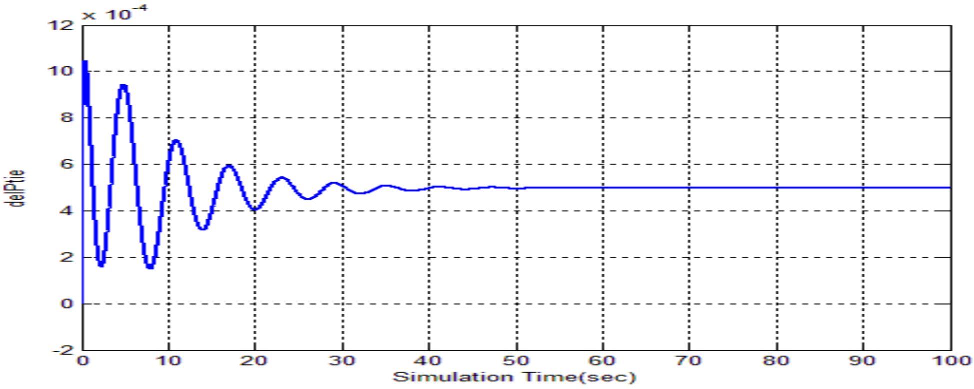

Fig. 5 Tie-line power deviation for hybrid test system with 20% renewable penetration using GA.

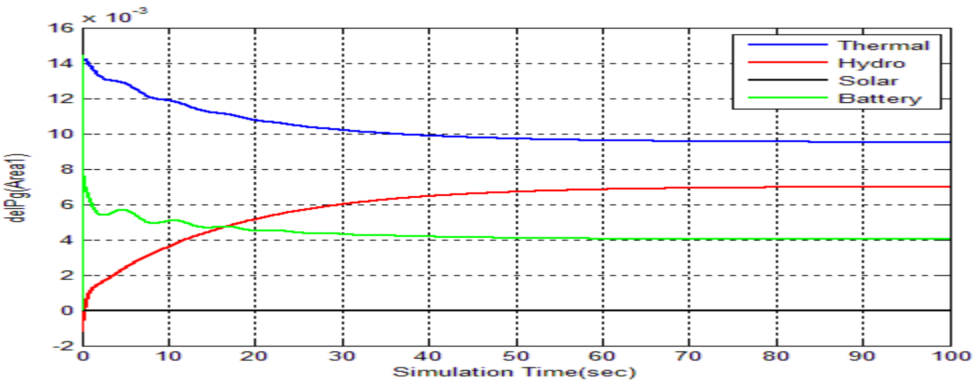

Fig. 6 Incremental power generation by GENCOs in area-1 for hybrid test system with 20% renewable penetration using GA

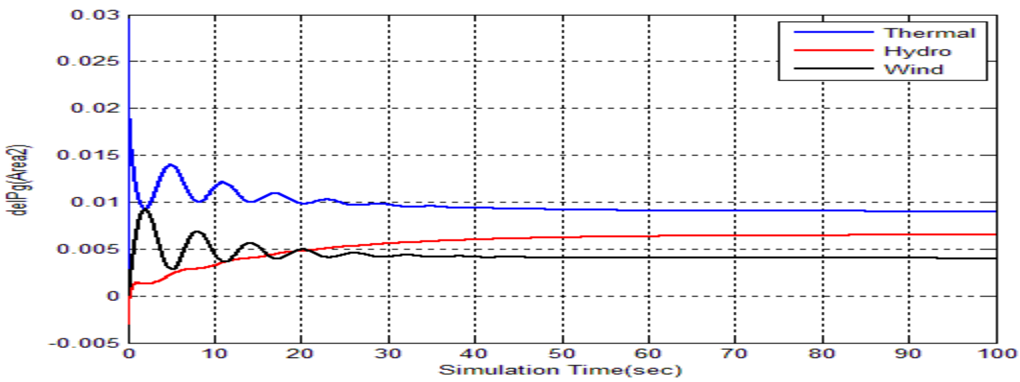

Fig. 7 Incremental power generation by GENCOs in area-2 for hybrid test system-I with 20% renewable penetration using GA

CONCLUSION

The present work deals with the study of dynamics of frequency and tie line power in a restructured multi-area hybrid power system that utilizes a classical PID control based load frequency control scheme. The success of this load frequency scheme primarily depends on the parameter settings of the PID controller. Hence, in this work Genetic algorithm (GA) is implemented to optimize the parameter settings of PID controllers used in the LFC scheme. The results confirm that the genetic algorithm provides fast and accurate tuning of parameters of PID controller with less overshoot, faster response, less setting time and good convergence rate.

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