LOAD FREQUENCY CONTROL OF TWO AREA THERMAL POWER SYSTEM USING CRAZINESS BASED PARTICLE SWARM OPTIMIZATION

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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 zeros. 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 problem of selecting and tuning the parameters of a load frequency controller using Craziness Based Particle Swarm Optimization is discussed in this thesis. The proposed method has been applied to a two area thermal reheat power system with governor dead band. Optimum proportional and integral controllers using the concept of Particle Swarm Optimization have been obtained. Simulation results confirm the designed control performance of the proposed control. The results show that the obtained optimal PI-controller improves the dynamic performance of the power system. This work is done using MATLAB/ SIMULINK 7.12 software**.**

Index Terms **- Automatic Generation Control, PI controller, Load Frequency Control, Particle Swarm Optimization**

I. INTRODUCTION

An interconnected electric power system generates transports and distributes electric energy. The aim of such these systems is to supply electric energy with nominal system frequency and terminal voltage, values and tolerances of those are defined by some power quality standards. According to power system control theory, a nominal system frequency depends on the balance between generated and consumed real powers [1]. The difference between generated power and instant load demand causes changing of nominal system frequency at the normal state. If the amount of generated power is less than the demanded amount, speed and frequency of the generator units begin to decrease, and vice versa. Hence, the amount of production of the synchronous generators is made sense for frequency deviations occurred in the power system in order to maintain that balance. For this purpose, an automatic generation control concept is used.

The aim of automatic generation control is that the steady state error of the system frequency deviations following a step load demand is made zero error. When the literature is investigated, it can be seen that early works on AGC was initiated by Cohn [2]. However, a modern optimal control concept for AGC designs of interconnected systems is put forward by Elgerd and Fosha for the first time [3]. They suggested a proportional controller and different feedback form to develop optimal controller. Until the present day, lots of different control strategies such as conventional, adaptive, variable structure, robust and some based on artificial intelligence have been reported [4]. However, gain scheduling adaptive control can be distinguished from the other control techniques because it makes the process which is under control less sensitive to changes in process parameters and in particular, it is also simpler to implement than the other modern control techniques.

For these reasons, it is carried out to AGC system, frequently. The first gain scheduling control method for AGC of interconnected power system was proposed by Lee and coworkers in 1991 [5]. Their controller provided better control performance for a wide range of operating conditions than the performances obtained so far. Later on, Rubaai and Udo presented a multi-variable gain scheduling controller by defining a cost function with a term representing the constraints on the control effort and then minimizing that with respect to the control vector [6]. Since the conventional gain scheduling methods may be unsuitable in some operating conditions due to the complexity of the power systems such as nonlinear load characteristics and variable operating points, a usage of artificial intelligence based methods were preferred by researchers from the beginning of these dates.

II. MODELLING OF A TWO-AREA INTERCONNECTED POWER SYSTEM WITHOUT GOVERNOR DEAD BAND

A two-area system consists of two single areas connected through a power line called the tie-line. Each area feeds its user pool and the tie-line allows electric power to flow between areas. Since both areas are tied together, a load agitation in one area affects the output frequencies of both areas as well as the power flow on the tie-line. The frequency control is accomplished by two different control actions in interconnected two area power systems: The primary speed control and supplementary or secondary speed control actions. The primary speed control makes the initial vulgarre adjustment of the frequency. By its actions the various generators in the control area track a load variation and share it in proportion to their capacities.

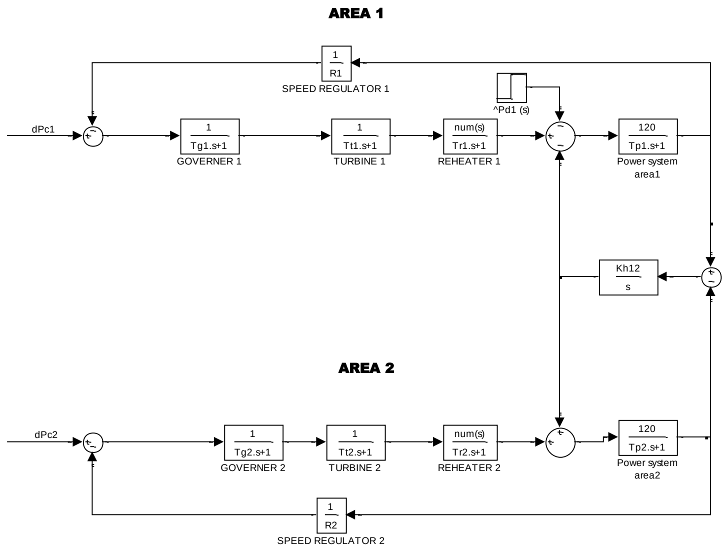

Fig. 1 Two-Area Interconnected Power System without Governor Dead Band

A two area system may be represented for the load frequency control in terms of its components. The components are namely speed governing system, turbine, governor- load system and tie line connecting two areas

Governor Dead band

Governor Dead band is defined as the total magnitude of a sustained speed change within which there is no resulting change. Though the speed governor characteristics are nonlinear they are approximated for linear analysis. The limiting value of governor dead band is 0.06%. One of the effects of governor dead band is to increase the apparent steady state speed regulation R. Turbine – Governor Dead bands are found due to backlash in the linkage connecting the piston to the camshaft. Backlash is the nonlinearity which causes governor dead band and tends to produce continuous sinusoidal oscillations with a natural period of about 2secs.

In the model, a governor dead-band effect is also added to all control areas to simulate nonlinearity. A governor dead-band is defined as the total magnitude of a sustained speed change where there is no change in valve position of the turbine. Describing function approach is used to represent the governor dead-band in the areas. The governor dead-band nonlinearity tends to produce a continuous sinusoidal oscillation of natural period of aboutT_0 = 2 s. This approach is being used to linearize the governor dead-band in terms of change and rate of change in the speed.

III. PSO Algorithm

Particle swarm optimization algorithm was introduced by Kennedy and Eberhart in 1995, as inspired from fish schooling and birds flocking, is a powerful yet simple optimization algorithm that can perform extensive exploration of the problem space. Besides, it does not rely on derivative information to guide the search toward the problem solution. Particle swarm optimization and some of its variants have been proposed and successfully applied to economic dispatch problems with piecewise quadratic cost functions [7-8].

The PSO algorithm is based on the behavior of individuals of a swarm developed by Kennedy and Eberhart. Its roots are in zoologist-modeling of the movement of individuals (i.e., fish, birds, and insects) within a group. It has been noticed that members of the group seem to share information among them to lead to increased efficiency of the group. The particle swarm optimization algorithm searches in parallel using group of individuals similar to other AI-based heuristic optimization techniques. Each individual corresponds to a candidate solution to the problem. Individuals in a swarm approach to the optimum through its present velocity, previous experience and the experience of its neighbours. In a physical n-dimensional search space, the position and velocity of individual i are represented as the velocity vectors. Using these information individual i and its updated velocity can be modified under the following equations in the particle swarm optimization algorithm. The flowchart of the particle swarm optimization is shown in Figure 2.

$$x_i^{k+1} = x_i^{(k)} + v_i^{(k+1)} \quad (5)$$

$$v_1^{k+1} = v_i^k + \alpha_i\left(x_i^{lbest} - x_i^{(k)}\right) + \beta_i\left(x_i^{gbest} - x_i^{(k)}\right) \quad (6)$$

Where,

$x_i^{(k)}$ is the individual i at iteration k

$v_i^{(k)}$ is the updated velocity of individual i at iteration k

$\alpha_i; \beta_i$ are uniformly random numbers between[0,1]

x_i^{lbest} is the individual best of individual i

x^{gbest} is the global best of the swarm

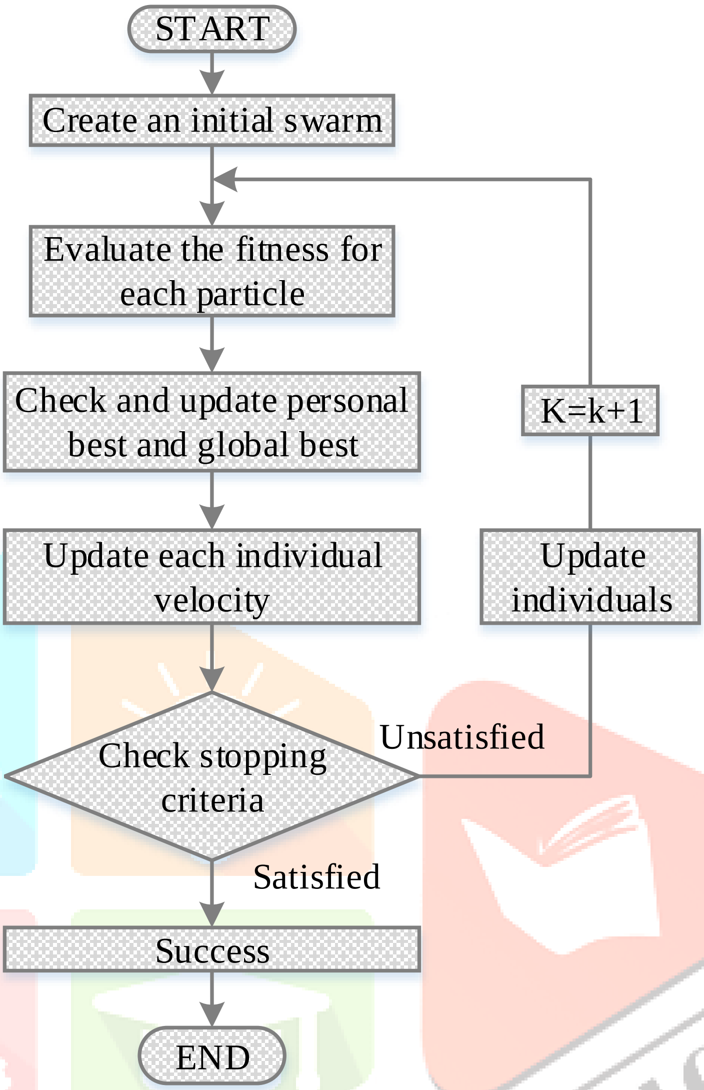

Fig. 2 Flowchart of the PSO algorithm

IV. PI CONTROLLER

The conventional PI controller is the simplest method of control and widely used in industries. Proportional plus Integral Controller increases the speed of response.

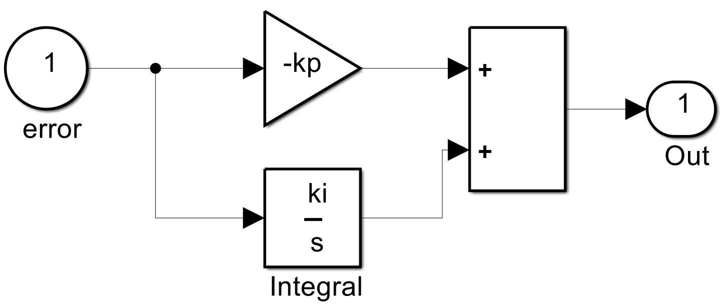

Fig. 3 Block diagram of PI controller

It produces very low steady state error. In this paper, ACE is given as input to PI controller and output is taken into the system. General equation of the PI controller is;

$$U(s) = K_P E(s) + \frac{K_i}{s} E(s) \qquad (7)$$

where Kp is proportional gain, K_i is the integral gain, E(s) is the controller input and U(s) is the controller output. Figure 3 shows the block diagram of PI controller. Ziegler Nichols' method of tuning is adopted to find the optimum value of Kp and Ki values. Table.1 shows the gain and ISE values of PI controller.

V. CRAZINESS BASED PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a population based optimization algorithm which is first introduced by Kennedy and Eberhart in 1995 [9]. It can be obtained high quality solutions within shorter calculation time and stable convergence characteristics by PSO than other stochastic methods such as genetic algorithm. PSO uses particles which represent potential solutions of the problem. Each particles fly in search space at a certain velocity which can be adjusted in light of preceding flight experiences. Since the standard PSO algorithm can fall into premature convergence especially for complex problems with many local optima and optimization parameters, the craziness based PSO algorithm which is particularly effective in finding out the global optimum in very complex search spaces is developed. As a control strategy, the new control configuration which is depicted in Fig. 4 is suggested. The CRAZYPSO algorithm can prevent the swarm from being trapped in local minimum, which would cause a premature convergence and lead to fail in finding the global optimum [10].

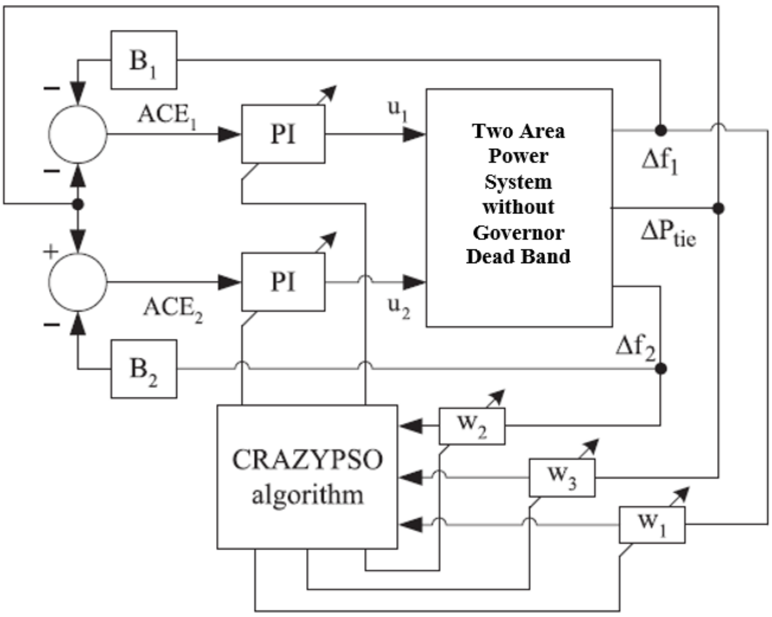

Fig. 4 The novel control strategy of AGC.

VI. RESULTS AND DISCUSSION

The Crazy PSO parameters for the simulation of load frequency control of a Two area thermal reheat power system without non-linearities and with governor dead band non linearity are shown in the Figs. 5-16 and Tables 1-4.

Table 1 Two area Thermal Power System Parameters

Parameter	Quantity
$T_{g1,2}$	0.2 s
$T_{r1,2}$	0.3 s
$K_{p1,2}$	120 Hz/pu MW
$T_{p1,2}$	20 s
T_{12}	0.0707 MW/rad
$B_{1,2}$	0.425 pu MW / Hz
$R_{1,2}$	2.4 Hz/ pu MW
N*1*,*N2*	0.8, -0.02

Table 2 CRAZY PSO parameters

No of population	20
No of Iteration	50
Velocity of particles(c1,c2)	2,2
Weight of the particle	1,1
Incremental Velocity	10

6.1 Output of the system with ISE as Objective function

$$ISE = \int_0^t (ACE_i)^2 dt$$

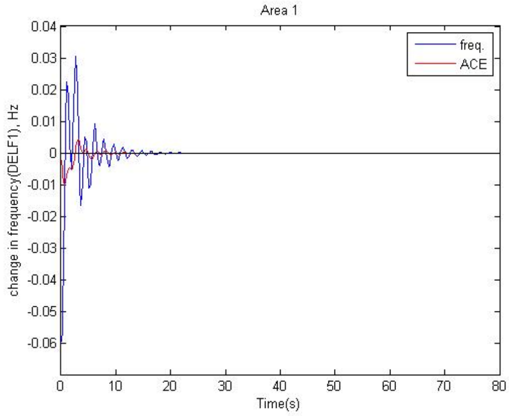

Fig. 5 Change in Frequency with respect to Time in area 1

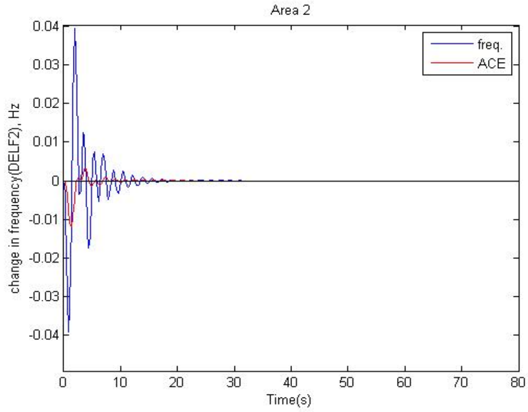

Fig. 6 Change in Frequency with respect to Time in area 2

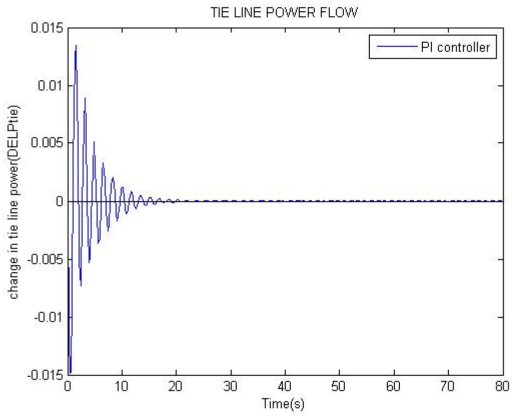

Fig. 7 Change in TIE line power flow with respect to Time

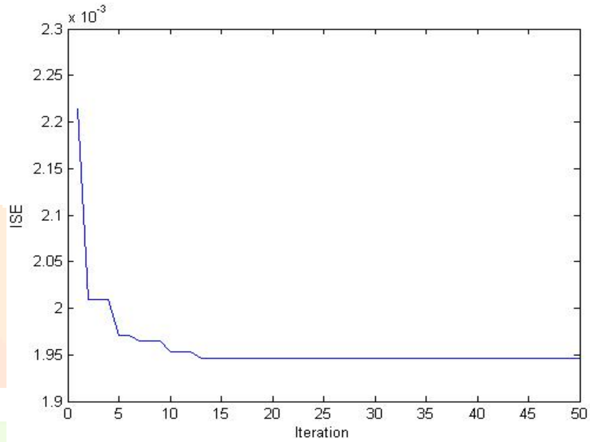

Fig. 8 Iteration vs proposed objective function

6.2 Output of the system with ITSE as Objective function

$$ITSE = \int_0^t t\,.(ACE_i)^2\, dt$$

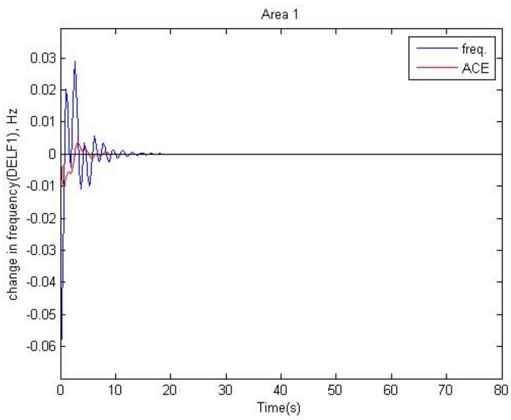

Fig. 9 Change in Frequency with respect to Time in area 1

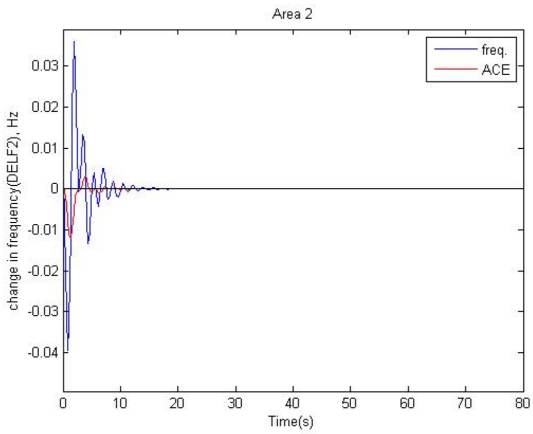

Fig. 10 Change in Frequency with respect to Time in area 2

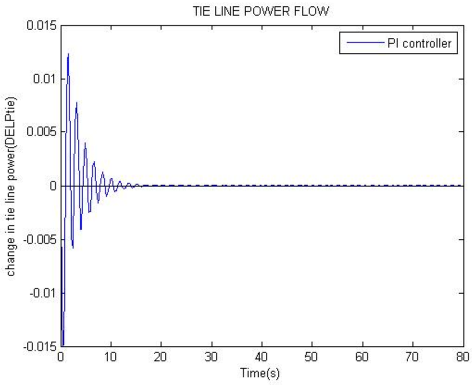

Fig. 11 Change in TIE line power flow with respect to Time

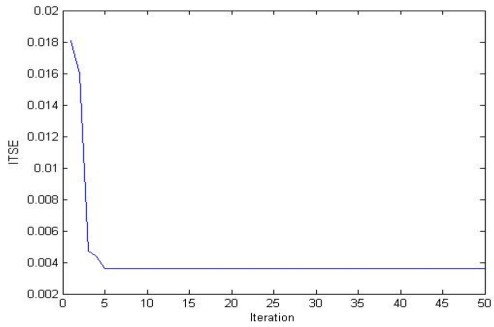

Fig. 12 Iteration vs proposed objective function

6.3 Output of the system with proposed Objective function

$$J = \int_0^t t\,[(w_1 \Delta f_1)^2 + (w_2 \Delta f_2)^2 + (w_3 \Delta P_{tie})^2]\,dt$$

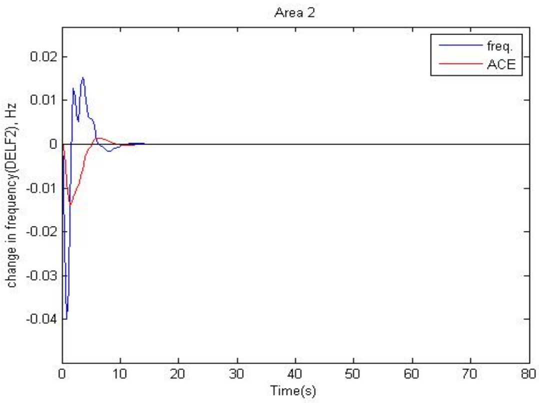

Fig. 13 Change in Frequency with respect to Time in area 1

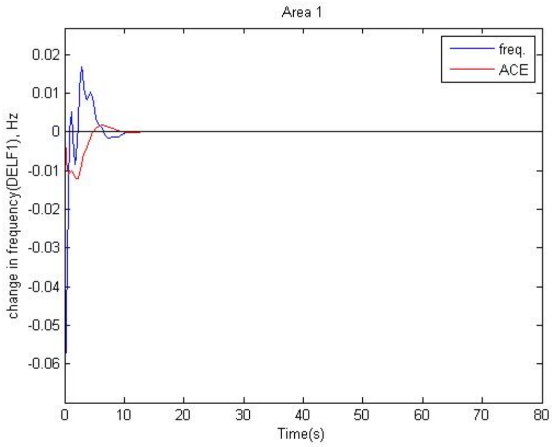

Fig. 14 Change in Frequency with respect to Time in area 2

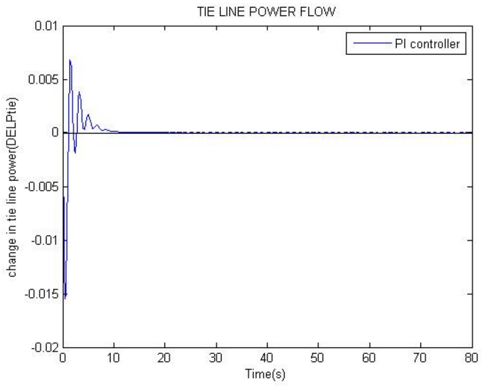

Fig. 15 Change in TIE line power flow with respect to Time

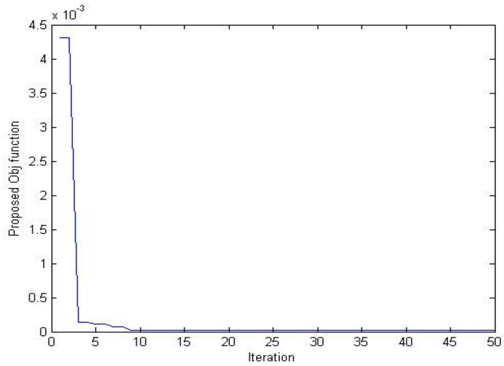

Fig. 16 Iteration vs proposed objective function

Table 3 Tuned parameters with ISE, ITSE and proposed cost functions.

	Kp	Ki	W1	W2	W3
ISE	0.2930	-0.4882	-	-	-
ITSE	0.3282	-0.4483	-	-	-
Proposed Objective function	0.2476	-0.1194	0.1908	0.6043	0.6650

Table 4 Settling times with ISE, ITSE and proposed cost functions.

	Settling time	Peak value
ISE	20s	0.04
ITSE	15s	0.03
Proposed Objective function	18s	0.015

VII. CONCLUSION

In this article, the new gain scheduling PI-controller strategy is proposed for Load Frequency control (LFC). In this strategy, the control is evaluated as an optimization problem, and the weight coefficients of the cost function are also optimized as the controller gains have been done. CRAZYPSO algorithm which is one of the recent population based optimization algorithms is used because of its convergence superiority in order to optimize the parameters and also its short and simple codes. The performance of the proposed controller is compared with the performances which are obtained with standard ISE and ITSE cost functions. On the other hand, the robustness of the control strategy with the proposed cost function-1 is also investigated. Then, it can be said that this control approach is the effective and the relatively robust strategy in order to provide optimal automatic generation control to the power system, and the choosing suitable cost function is also quite important for performance of the convergence to the best solution. Finally, due to its superiorities, the proposed control strategy can be applied to the different control system applications, successfully.

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