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Load Frequency Control of Two Area Thermal System Using Sine-Cosine Algorithm

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Abstract

Load Frequency Control / Automatic Generation Control is very essential mechanism in modern power system. It makes balance between the power generated and demand of each control area for the sake of maintaining the system frequency at the nominal value and tie-line power at the scheduled value. For this purpose, a fast acting controller is desirable for maintaining the system frequency nominal. In this thesis work, a newly developed Sine-Cosine Algorithm (SCA) has been proposed in order to optimize the gain of the controller for two-area interconnected power system and results obtained from this algorithm is compare with the other classical techniques. The responses of the proposed algorithm are demonstrated by MATLAB simulation.

Keywords: Load Frequency Control (LFC), Automatic Generation Control (AGC), Area Control Error (ACE), Sine-Cosine Algorithm (SCA), Integral Squared Error (ISE).

1. Introduction:

The main role of power system is to convert the natural energy into electrical energy. In an interconnected power system maintaining the nominal frequency and power exchange over the tie-lines becomes a very complicated task. There is a direct impact of change in frequency from the nominal value to power system and its equipments and also affects the reliability of the system. Need of maintaining the system frequency to nominal value because; speed of AC motors directly depends on frequency, turbines blades gets damaged due to change in frequency and also transformer goes into the saturation with reduced frequency. Change in frequency causes change in the real power and voltage variation causes change in the reactive power. Therefore they are controlled separately. The above two problems can be overcome by measuring control error signal, known as Area Control Error (ACE). Area Control Error is produced by taking comparison between the feedback and reference signal and provide to the particular controller. So, we have first calculate the Area Control Error by Integral Squared Error (ISE) and then taking gain of that controller at which the system error is decreased.

2. Automatic Generation Control:

The chief purpose of the Automatic Generation Control (AGC) is to reinstate the system frequency to the nominal value and maintains the power exchange over the tie-lines, when there is change in system loads. The main functions of the AGC are to; maintain the steady frequency; control the tie-line flows and distribute the load among the participating generating units. Thus as the load changes continuously in the system, the generation is adjusted automatically to make the frequency to its nominal value.

3. Optimization Techniques:

There are several modern as well as classical techniques has been applied for automatic generation control in multi-area interconnected power system in order to optimize the gain of the controller to restore the nominal value of the frequency and maintains the power exchange over the tie-line. Classical techniques like; Newton Raphson method, Gradient Search method, Linear Programming, Dynamic Programming etc. Modern or meta-heuristic techniques become very popular now days because of their simplicity, flexibility, derivation free mechanism and local optima avoidance. These techniques are simple, mostly enthused from the physical phenomena, animal's behavior or evolutionary concepts. These techniques are flexible in nature means; applied to different problems without making any special change in the structure of the technique. And most important feature is that, many of these techniques are never trapped into the local optima. Meta-heuristic techniques are classified into two categories: individual solution based and population based techniques. In individual solution based techniques only one candidate solution is optimize over the course of iteration and in population based techniques a set of candidate solutions is optimized over the course of iterations, this guaranties the local optima avoidance.

4. Sine-Cosine Algorithm (SCA):

Sine-Cosine Algorithm is a population based meta-heuristic technique which starts the optimization process with a set of random solutions. This random set is evaluated constantly by an objective function and enhanced by set of rules. With the large number of candidate solutions probability of finding global solution is increased. In this algorithm following position updating equations are:

$$X^{t+1}_i = X^t_i + r_1 \times \sin(r_2) \times r_3 P^t_i - X^t_i \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$X^{t+1}_i = X^t_i + r_1 \times cos(r_2) \times r_3 P^t_i - X^t_{ii} \quad \ldots\ldots\ldots\ldots..(2)$$

Where X^t_i is the position of current solution in i-th dimension at t-th iteration, r1/r2/r3 are the random numbers, Pi is position of the destination point in the i-th dimension.

$$X^{t+1}_i = \begin{cases} X^t_i + r_1 \times \sin(r_2) \times r_3 P^t_i - X^t_i & r4 < 0.5 \\ X^t_i + r_1 \times cos(r_2) \times r_3 P^t_i - X^t_{ii} & r4 > 0.5 \end{cases} \quad \ldots\ldots\ldots (3)$$

Where r4 is a random number in [0,1]

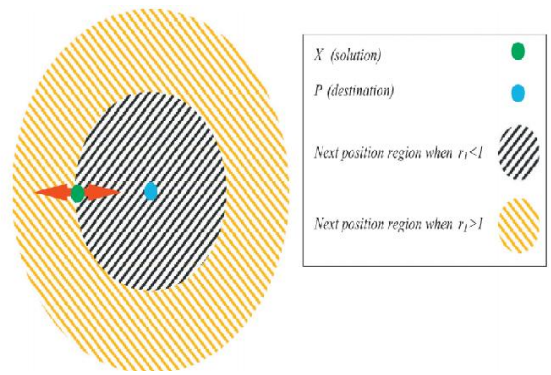

Fig.1 Effect of sine cosine in eqn. (1) and (2)

In the above equations there are four main parameters r1,r2,r3 and r4. The parameters r1 tells that the next position region between solution and destination or outside it. Parameter r2 dictates how far the movement should be towards or outwards the destination. The parameter r3 brings the random weight for destination in order to stochastically force (r3 > 1) or deemphasize (r3 < 1) the effect of destination in defining the distance. And parameter r4 equally switches between sine and cosine component in eqn. (3)

Fig. 1 shows that how the space between the two solutions in the search space is define by the proposed equations. The cyclic pattern of sine and cosine function defines the position of solution around another solution. Also this can provide guarantee exploitation of the space between two solutions. By changing the range of sine and cosine function we can explore the search space.

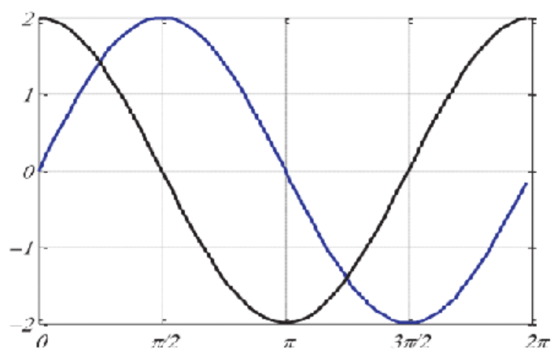

Fig.2 Sine Cosine with ranges of [-2,2]

The effects of sine and cosine function with ranges [-2,2] is illustrated by the conceptual model as shown in the fig.3. This figure tells that how position of solution can be updated by changing the range of sine and cosine function. This can guarantees exploration and exploitation of the search space respectively.

For make balance between exploration and exploitation, the range of sine and cosine in eqn. (1) to (3) is changed adaptively using equation:

$$\left(\mathbf{r_1 = a - t\, a/T} \right)$$

where **t** is current iteration, **T** is maximum number of iterations and **a** is constant.

SCA explores the search space when ranges of sine and cosine function are in (1,2] and [-2,-1] and exploits the search space when ranges are in [-1,1solution can be updated by changing the range of sine and cosine function. This can guarantees exploration and exploitation of the search space respectively.

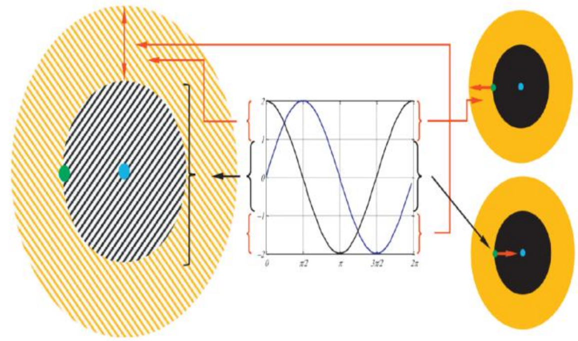

Fig. 3 Sine and Cosine with the ranges in [-2,2] to go around the destination

5.General steps of Sin-Cosine Algorithm (SCA)

Initialize a set of search agents (solutions) (X)
Do
Evaluate each of the search agents by the objective function
Update the best solution obtained so far (P=X)
Update r1, r2, r3, and r4
Update the position of search agents using eq. (3)
While (t< maximum number of iterations)
Return the best solution obtained so far as the global optimum.

6.Simulation Results

To prove the usefulness of the proposed technique in the area of load frequency control, we optimize the controller gains of area 1and area 2 in the simulink model of two area interconnected thermal system and also obtained the Tie-line power.

Table-1 Optimized value of the integral controller with SCA

Optimum Parameters	SCA
Ki1	0.2750
Ki2	0.0449

7. Simulation Graph

When putting the values of ki1 and ki2 in the simulink model, the frequency graphs of areas 1 and 2 are obtained by using SCA algorithm.

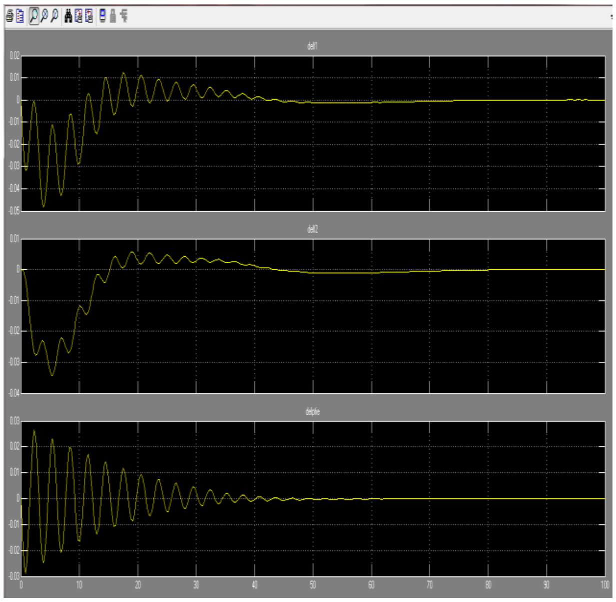

Table-2 Nominal Parameters of the system

Nominal parameters	*Values*
Rating of each area	**2000 MW**
Base power	**2000 MVA**
R1=R2	**2.4 Hz/p.u MW**
B1=B2	**0.425 pu MW/Hz**
F	**60 Hz**
ΔPd1	**0.01 pu MW/Hz**
Tg1=Tg2	**0.08 s**
Tr1=Tr2	**10 s**
Kr1=Kr2	**0.5**
Tt1=Tt1	**0.3**
Kp1=Kp1	**120 Hz/p.u MW**
Tp1=Tp1	**20 s**
A	**0.5**

8. Conclusion

In this paper, the integral controller gains (ki1 and ki2) of two area interconnected thermal has been optimized by using recently developed *Sine-Cosine Algorithm (SCA).* The results obtained from proposed algorithm is then compared with the very successful modern technique i,e Grey Wolf Optimization (GWO) technique [49]. The proposed algorithm shows better results than GWO technique. The algorithm is planned in MATLAB (R2013b) and simulink environment.

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