Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

Artificial Fish Swarm Algorithm based Optimization of Load Dispatch Problem for GTCC Units

Yongmei Wang
College of Information Engineering
Zhengzhou University
Zhengzhou, China

***Abstract*—Load dispatch problem lies at the kernel among different issues in GTCC units' operation, which is about minimizing the fuel consumption for a period of operation so as to accomplish optimal load dispatch among units and in return satisfying the total load demand and operation constraints. This paper analyses the load dispatch model of gas turbine combined-cycle (GTCC) units and utilize a swarm intelligence algorithm to optimize the solution of the model. AFSA is motivated by intelligent collective behavior of fish groups in nature. Due to fish swarm behaviors such as random behavior, chasing behavior, swarming behavior and searching behavior, it shows characteristics such as non-sensitive initial artificial fish location, flexibility, high convergent speed, global optimal capacity and so on. Simulations were performed by building up models using data from previous literature and optimizing the solutions of the models by AFSA. The simulations show that AFSA can get a better effect than equal micro incremental method used in previous literature. The operating economy is proved through the results obtained by AFSA. It can be concluded that AFSA is quite effective in solving the optimization of load dispatch problem of GTCC units.**

Keywords—GTCC units; Load dispatch; Artificial Fish Swarm Algorithm

INTRODUCTION

Due to the advantages [1,2] of GTCC units and the availability of natural gas, GTCC units continue to gain strength in power industry. In this situation, economic operation of the units becomes much important. And load dispatch problem lies at the kernel among different issues in GTCC units' operation [3,4].

The load dispatch problem is about minimizing the fuel consumption for a period of operation so as to accomplish optimal load dispatch among units and in return satisfying the total load demand and operation constraints. To establish the load dispatch model is necessary for the calculation of the problem. In fact, performance of GTCC unit varies with many factors [5-7]. This will lead to variation of load dispatch model. Environmental factors are uncontrollable and always changing with time and location. So influences of environmental conditions on establishing the load dispatch model is briefly discussed.

Mathematically, the problem of load dispatch is a complex nonlinear problem containing integer and continuous variables. Many efforts [8-10] have been made to solve the problem, through various mathematical programming and optimization techniques. But these methods all have certain limitations. For example, lambda iteration needs the formulation in continuous differentiable form. Consequently, this method is unable to solve discontinuous load dispatch problems. Besides, they need high computation time solving large size load dispatch problems and sometimes fail to provide global optimal solution.

With the development of computer technology and artificial intelligence, modern intelligent algorithms [11-14] show great advantages in solving load dispatch problems, which mainly includes artificial neural network, simulated annealing, ant colony optimization, genetic algorithm and artificial fish swarm algorithm. Among them, artificial fish swarm algorithm (AFSA)[15] is a method through simulating the behavior of the fish swarm inside water, which attracts much attention recently. An artificial fish is a fictitious entity whose movements are simulations of fish behaviors[16,17] such as chasing behavior, swarming behavior, searching behavior and random behavior. Local optimization of individuals will eventually lead to the global optimization. Due to strong robustness for initial parameters, global optimization and parallel computing, it is successfully applied in solving optimization problems[18]. Simulations were performed by building up models using data from previous literature [19] and optimizing the solutions of the models by AFSA. The simulations show that AFSA can get a better effect than equal micro incremental method used in the literature. And the operating economy is proved though the results obtained by AFSA. It can be concluded that AFSA is quite effective in solving the optimization of load dispatch problem of GTCC units.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

LOAD DISPATCH MODEL OF GTCC UNITS

The load dispatch optimization of GTCC units is to find the optimum combination of units that minimizes the total gas consumption while satisfying the total load demand and operation constraints. In order to analyze the problem through a mathematical model, the total gas consumption of all the GTCC units is described as a function of units' power outputs. And to optimize the solution of the load dispatch problem is to get the values of each unit's power output while the total gas consumption function achieves a minimum. Thus the formulation of a GTCC units load dispatch problem with operation constraints can be described as follows.

$$\begin{cases} \min F = \sum_{i=1}^{n} U_i \cdot f_i(P_i) \\ s.t. \quad \sum_{i=1}^{n} U_i P_i = P_D \\ P_{i\min} \le P_i \le P_{i\max} \\ \sum_{i=1}^{n} U_i P_{i\max} \ge P_D + R \end{cases} \quad (1)$$

where F is the objective function corresponding to the total gas consumption (in m^3/h); n is the total number of GTCC units. $f_i(P_i)$ is the gas consumption for the ith unit (in m^3/h); P_i is the power output of unit i (in MW); n is the number of units in the system; U_i represents ith unit's running state and it can only be 0 or 1 which represents stop or running. P_D is the system's total demand (in MW); $P_{i\min}$ and $P_{i\max}$ are the lower and upper bounds for power outputs of the ith unit. (in MW); R is the spinning reserve and generally $R = 0.07P_D$ is adopted.

For gas consumption function $f_i(P_i)$, binomial expression is usually adopted to fit its characteristic curve as follow.

$$f_i(P_i) = a_i P_i^2 + b_i P_i + c_i \quad (2)$$

where a_i, b_i, c_i are the gas consumption characteristic coefficients of each unit.

There are some simplified hypotheses of the model: All the n units can be arranged to start and stop; fuel consumption for start or stop is not considered; line losses are not considered; the fuel property of natural gas is constant; and the total load demand keeps constant within a certain interval.

In the model above, $P_{i\min}, P_{i\max}$ are influenced by the performance of GTCC units. And the performance of a GTCC unit varies with many factors, such as environmental conditions, condenser pressure, inlet and exhaust losses, fuel properties, etc. The influences of conditions are important factors. The main environmental factors influencing the performance of GTCC units are ambient temperature, barometric pressure and relative humidity. When the ambient temperature increases, the power output of the combined cycle is reduced and very slight variation in heat consumption rate. The output and the barometric pressure generally decrease proportionately, but for the plant already installed, the variation of this variable is so subtle that can be neglected. The power output of the GTCC units increases while other parameters remain constant. However, the variation is to be too small to be considered. So to build the model of GTCC units' load dispatch problem more scientifically, considering the influence of environmental is important.

Optimization of the load dispatch problem for GTCC units by Artificial Fish Swarm Algorithm

3.1 Overview of Artificial Fish Swarm Algorithm

Artificial fish swarm algorithm (AFSA), proposed by Li Xiao Lei in 2002, is a stochastic population-based algorithm motivated by intelligent collective behavior of fish groups in nature.

In AFSA, a population of artificial fishes move towards an objective by performing some behaviors such as Swarm, Follow, and Movement.

Movement– in general, fish swims randomly in water looking for food and other companions. Follow–when a fish, or a group of fishes, in the swarm discovers food, the others in the neighborhood find the food dangling quickly after it. Swarm–when swimming, fish naturally assembles in groups which is a living habit in order to guarantee the existence of the swarm and avoid dangers. Prey–this is a basic biological behavior since fish tends to the food, when fish discovers a region with more food, by vision or sense, it goes directly and quickly to that region. Artificial fishes do the optimization process by performing the behaviors above. AFSA has characteristics such as non-sensitive initial artificial fish location, flexibility and fault tolerant. It has been applied on different problems.

3.2 The procedure for Artificial Fish Swarm Algorithm

The main steps of AFSA include encoding, initialization, building a fitness function selection, crossover, mutation, information exchange and elitist strategy.

Step 1. Establishing food consistence function:

In AFSA, the searching procedure is to find the highest food consistence. For the load dispatch problem in this paper, the food consistence function can be described as follow.

$$g = -\sum_{i=1}^{n}[U_i \bullet f_i(P_i)] - C(\sum_{i=1}^{n} U_i P_i - P_D)^2 \quad (3)$$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

where C is a penalty factor which usually takes a large value. In the function above, it can lead to small value of the function if a solution does not satisfy the constraints, so the solution will be deleted.

Step 2 Initializing:

Initialize a swarm of N fishes. Each fish is represented by a group of real numbers. The initial values of all the fishes are generated randomly. For example, for the load problem of two units, the variables need to be optimized are x_1, x_2, whose ranges are [a,b]and[c,d]. So a fish swarm of 2 rows and N columns will be generated, where each column represents a fish and N is the size of the swarm.

Step 3 Swarming:

If the current location of an artificial fish is X_i, it will search for the companions within its visual range. The number of its companions is n_f and the centroid for them is X_c. The food consistence of X_i, X_c are Y_i, Y_c. If $\frac{Y_c}{n_f} > \delta Y_i$ (δ is congestion), it indicates that the localtion of the centroid has a higher food consistence and is not so crowed. So the swarming behavior will move one step forward the centroid X_c. If not, the preying behavior will be performed. The preying behavior is like this: The artificial fish in X_i selects a location X_j randomly within its visual range; if $Y_i < Y_j$, it indicates that the food consistence in X_j is higher; So the preying behavior will move one step forward to X_j; if not, it will select another position X_j randomly again and judges whether move forward or not; iterating as above until the maximum timess of preying behavior; if the condition for moving forward is still not satisfied, the artificial fish will move one step randomly.

Step 4 Following:

An artificial fish in location X_i searches the area within its visual range and the number of its companions n_f within the area and the one X_{max} with highest food consistence Y_{max} has been found. If $\frac{Y_{max}}{n_f} > \delta Y_i$, the following behavior will perform one step forward to the companion X_{max}. Otherwise, the fish will perform the preying behavior as described previously.

Step 5 Shifting strategy:

Evaluate the circumstance of an artificial fish. That is, select the one which leads to higher food consistence from the swarming behavior and following behavior.

Step 6 Iterative computation:

Set up a bulletin board so as to prevent the best fish and decide when to stop the iteration of the behaviors. Each artificial fish's status will be compared the record on the board. If the location of the fish is better than that of the bulletin board, the record on the bulletin board will be substituted by the artificial fish. Then the algorism go back to step 3 and the process will be repeated iteratively until the maximum iteration number is achieved.

SIMULATION

In paper [19] the author uses equal micro incremental to optimize the load dispatch of 3×390MW gas turbine generation units. In this paper, the gas consumption characteristic equations from paper [19] are used for the calculation of optimal load dispatch by AFSA.

According to paper [19] the characteristic coefficient of gas consumption function and bound constraints are shown in Table 1.

TABLE 1. Gas consumption character coefficient and limit of load

date	unit	ai	bi	ci	[pmin, pmax]
7.25	1	0.11837	84.002	16725	[234, 390]
7.25	2	0.12583	75.695	18274	[234, 390]
10.26	1	0.058427	117.29	11904	[234, 390]
10.26	3	0.12681	71.863	17860	[234, 390]

Suppose the constraints are already revised according to the ambient conditions for lack of related data. Take total load PD=505MW on July 25, 2007 as an example. The food consistence function is described as follow.

$$g = \sum_{i=1}^{3} U_i \bullet f_i(P_i) + C(\sum_{i=1}^{3} U_i P_i - P_D)^2 \qquad (4)$$

The units in operation are just 1# and 2#, so U1=U2=1，U3=0. Take 100 for the penalty factor C.

$$\begin{cases} f_1(P_1) = 0.11837P_1^2 + 84.002P_1 + 16725 \\ f_2(P_2) = 0.12583P_2^2 + 75.695P_2 + 18274 \end{cases} \qquad (5)$$

In this AFSA, the size of the swarm is set to 100; the maximum iteration number is 350; the maximum number of preying behavior is 100; the visual range is 2.5; the congestion is 0.618; the length of step is 0.1. The process for AFSA to optimize the load dispatch model is shown in Figure 2.

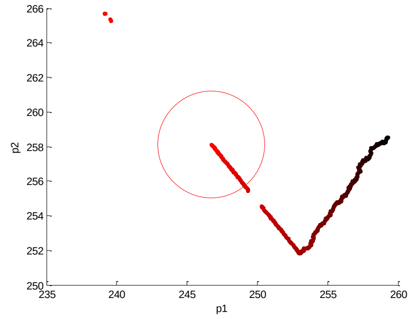

Fig.1. Movement of optimal load dispatch

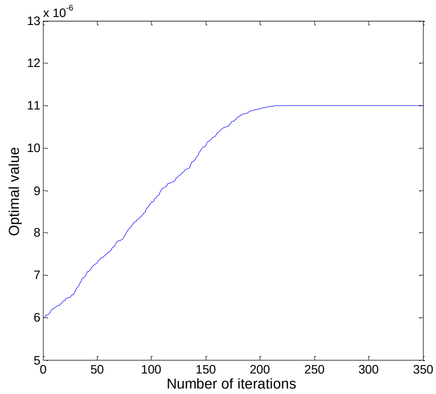

Fig.2. Iterative process of AFSA

Through the optimization of AFSA, the minimum value of fitness function reaches 1.10056×10^{-5}, when the load of 1# unit 246.72MW and 2# unit 258.13 MW. The total gas consumption is 90852.59m3N/h.

Results and discussions

Using the foregoing AFSA method to optimize the load dispatch problem of GTCC units, all the results obtained by AFSA are compared with those by other methods, as shown in Table 2 and Table 3.

TABLE 2. Load dispatch results of 1#,2# by different methods On July 25,2007

Load MW	P1 (AFSA) MW	P2 (AFSA) MW	1# gas consumption (AFSA) m3 N /h	2# gas consumption (AFSA) m3 N /h	Total gas consumption (AFSA) m3 N /h	Equal micro incremental method m3 N /h	AGC m3 N /h
505	246.72	258.13	44655.22	46197.37	90852.59	90870.67	98274.51
542	261.86	279.98	46838.47	49330.72	96169.19	96192.57	98427.58
600	291.88	307.95	51328.32	53516.48	104844.80	104871.10	104935.59
660	322.89	336.93	56189.93	58062.09	114252.02	114280.70	117339.50
700	343.42	356.39	59533.74	61233.32	120767.06	120797.70	122443.95

TABLE 3. Load dispatch results of 1#,3# by different methods On October 26,2007

Load MW	P1 (AFSA) MW	P3 (AFSA) MW	1# gas consumption (AFSA) m3 N /h	3# gas consumption (AFSA) m3 N /h	Total gas consumption (AFSA) m3 N /h	Equal micro incremental method m3 N /h	AGC m3 N /h
491	234.00	256.85	42549.09	43041.73	85590.82	87114.16	88041.39
500	234.02	265.82	42552.29	43637.97	86190.27	88507.33	87778.98
600	287.73	312.10	50489.24	50889.74	101378.98	103229.10	103538.45
651	323.25	327.57	55923.23	54697.11	110620.34	111009.30	119029.83
701	358.03	342.78	61387.44	58489.48	119876.92	118737.80	119029.83

Syst,2002;17(1):108–12.

According to the results above, AFSA could achieve savings of total gas consumption compared to the equal micro incremental method and AGC instruction. For instance, On October 26, 2007, when the total load demand is 500MW, the load dispatch results of unit 1# and 3# are 234.10MW and 265.26MW. The gas consumption is 42563.81m3N/h and 43606.07m3N/h respectively. The total gas consumption is 86169.88m3N/h, which has a reduction of 2317.06m3N/h compared to equal micro incremental method and 1588.71m3N/h compared to AGC instruction. It indicates that using AFSA to optimize the load dispatch problem of gas turbine units can improve the economic efficiency of the units.

CONCLUSIONS

In this paper, the dispatch problem of gas turbine combined-cycle units is proposed and the artificial fish swarm algorithm is employed on the optimization of the problem. Simulations were performed with AFSA method and the optimization results are compared with equal micro incremental method. Almost all the results obtained by AFSA in the simulations are better than other methods. With AFSA method the gas consumptions are significantly reduced. The searching processes show that AFSA has good characteristics of globally optimization, fast convergent speed robustness for initial values and so on. The findings indicate that AFSA has an advantage in the optimization of operation of gas turbine units. This work will contribute to the operation of GTCC units.

REFERENCES

[1] T.S. Kim, S.H. Hwang, Part load performance analysis of recuperated gas turbines considering engine configuration and operation strategy, Energy, 31 (2006) 260–277

[2] S.H. Yousef, Najjar, Comparison of performance for cogeneration systems using single- or twin-shaft gas turbine engines, Applied Thermal Engineering,Volume 17, Issue 2, February 1997, Pages 113–124

[3] B.K. Panigrahi, Salik R. Yadav, Shubham Agrawal, M.K. Tiwari, A clonal algorithm to solve economic load dispatch, Electric Power Systems Research 77 (2007) 1381–1389

[4] W-M Lin, F-S Cheng, M-T. Tsay, An improved tabu search for economic dispatch with multiple minima. IEEE Trans Power

[5] C. Yang, Z. Yang, R. Cai. Analytical Method For Evaluation of Gas Turbine Inlet air Cooling in Combined Cycle Power Plant," Applied Energy 86 (2009) 848–856

[6] C. Chuang, D. Sue, Performance effects of combined cycle power plant with variable condenser pressure and loading, Energy, 30 (2005) 1793–1801.

[7] D. Sanchez, R. Chacartegui, J.M. Munoz, A. Munoz, T. Sanchez, Performance analysis of a heavy duty combined cycle power plant burning various syngas fuels, International journal of hydrogen energy, 35 (2010) 337–345.

[8] C.L. Chen, S.C. Wang,Branch and bound scheduling for thermal generating units, IEEE Trans. Energy Convers. 8 (June (2)) (1993) 184–189.

[9] B.H. Chowdhury and S. Rabman, A Review of Recent .4dvances in Economic Dispatch, IEEE Trans Power Systems. Vol. PWRS-5, No.4, 1990.p. 1248-1257.

[10] M. Huneault and F.D. Galiana, Survey of the Optimal Power Flow Literature, IEEE Trans. Power Systems, Vol PWRS-6. No.2, May 1991, pp. 762-770.

[11] Y. L. Kwang, S.-Y. Arthit, J. H. Park, Adaptive Hopfield Neural Networks for Economic Load Dispatch, IEEE Transactions on Power Systems, Vol. 13, No. 2, May 1998

[12] R. Naresh, Dubey J, Sharma J. Two phase neural network based modeling framework of constrained economic load dispatch. IEEE Proc Gen Transm Distrib 2004; 151(3):373–8.

[13] C.K. Panigrahi, P.K. Chattopadhyay, R.N. Chakrabarti, M.Basu, Simulated annealing technique for dynamic economic dispatch, Electric Power Compo Syst, 2006;34:577–86.

[14] J.E. Lansbeny, L.Wozniak, Adaptive hydrogenerator governor tuning with a genetic algorithm, IEEE Paper 93 WM 136-2 EC, presented at the IEEERES 1993 Winter Meeting.

[15] L.X. Li, Z.J. Shao , J.X. Qian, An Optimizing Method Based on Autonomous Animate: Fish Swarm Algorithm. In: Proceeding of System Engineering Theory and Practice, vol. 11, pp. 32–38 (2002)

[16] A.M.A.C.Rocha, T.F.M.C Martins, E.M.G.P. Fernandes, An augmented Lagrangian fish swarm based method for global optimization. J. Comput. Appl. Math. 235, 4611–4620 (2011)

[17] B., Gervasi, O, Iglesias, A., Taniar, D., Apduhan, B.O. (eds.) ICCSA 2011, PartIII. LNCS, vol. 6784, pp. 185–199. Springer, Heidelberg (2011)

[18] F. Shi, H.Wang, L.Yu. "Analysis of 30 Case about MATLAB Intelligent Algorithm," Beijing: Beihang University Press, 2011.

[19] X.Peng, C.Zhang, X.Wang, "Application Research of Optimal Load Dispatch on LNG Power Plant," Power System Protection and Control,2010,38(14): 84-87