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Application of Grey Wolf Algorithm for Unit Commitment Problem

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ABSTRACT: Unit commitment (UC) is an imperative task in power generation resource management. Moreover, it is critical to niche in reliability analysis of the power system into its design maneuver tactic. In this article UC considering generator outages are formulated to achieve the optimum UC scheduling in power systems. Then the real coded grey wolf optimization is developed to schedule for a better dispatch in UC problems with generator outages being considered. A 10 unit system is considered for to verify the effectiveness of the proposed approach for 24-h horizon. It is carried out without outages and with outages for 10 unit system. A proportional study is conducted to observe the collision of reliability constraint on the optimal solution obtained.

KEYWORDS: Unit Commitment, Economic Dispatch, Thermal Generator, Grey Wolf Algorithm.

I. INTRODUCTION

1.1. Thermal Unit Commitment

The shortcoming of BB method is the exponential growth in execution time with the system size. Though LR based solution methods concentrate on finding an appropriate primal solution while minimizing the duality gap, it requires large computation in obtaining the feasible solution. The MIP method uses a linear programming technique, but it calls for large computational requirement. The modified versions of PL, DP, LR and MIP have evolved to overcome their limitations.

A combination of LR-PSO has also been developed for the thermal UC solution A mathematical method using Outer-Inner Approximation (OIA) approach has also been reported Lingfeng Yang et al., has proposed projected MIP formulations of UC problem The mathematical – heuristic combination such as LR-EP has been reported for short-term thermal UC solution Dewan Fayzur Rahman et al., has reported the application of meta-heuristic search based methods for the thermal UC solution. A combination of Improved PL (IPL) and neighborhood search method has been suggested for solving thermal UC problems

However, these heuristic methods have few drawbacks like algorithmic parameter settings, premature phenomena, trapping into infeasible solution and computationally expensive. Hence, it is great significance to improve the existing optimization techniques or exploring new optimization techniques to solve thermal UC problem.

1.2. RCGWO as Tool

Recently, in the field of evolutionary computations, a new optimization algorithm, namely Grey Wolf Optimization (GWO) has been developed by inspiring the behavior of grey wolves. The GWO algorithm mimics the leadership hierarchy and the hunting mechanism of grey wolves in nature. Seyedali Mirjalili et al., have proposed the GWO algorithm and the algorithm is examined with standard test functions which provides very competitive solutions with other heuristic algorithms. Further, GWO is applied to solve engineering design optimization problems [33]. The advantages of GWO are simple, easy to implement and has few control parameters which motivates the authors to apply GWO for solving power scheduling problems of electric utilities.

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II. PROBLEM FORMULATION

2.1. Objective Function

The total cost, over the entire scheduling period is the sum of the running cost, start up cost and shut down cost of all the units. Accordingly, the overall objective function of the UC problem is stated as:

$$\min \; F_t = \sum_{t=1}^{T} \sum_{i=1}^{N} \left[F_i(P_i(t)) + SC_i(t) + SD_i(t) \right] \tag{1}$$

Generally, the fuel cost, Fi(Pi(t)) of unit i in any given time interval t is a function of the generator power output. The production cost of unit i can be approximated as a quadratic function of the real power outputs from the generating units and can be expressed as:

$$F_i(P_i(t)) = a_i + b_i P_i(t) + c_i P_i^2(t) \tag{2}$$

The generator start up cost depends on the time, the unit has been off prior to start up. In this work, time-dependent start up cost is used and is defined as follows:

$$SC_i = \begin{cases} h - \cos t_i & ; \quad T_i^{off} \le X_i^{off} \le T_i^{off} + c - s - hour_i \\ c - \cos t_i & ; \quad X_i^{off} > T_i^{off} + c - s - hour_i \end{cases} \tag{3}$$

The SD cost is usually given a constant value for each unit. (In this paper, the shutdown cost has been taken equal to zero for each unit).

The objective function, i.e., minimization of total cost Ft is subject to the system and generating unit constraints which are as follows:

2.2. System Constraints

Power Balance Constraint

System power balance on an hourly basis, where the total power generated must supply the load demand Pd(t):

$$Pd(t) = \sum_{i=1}^{N} P_i(t) \tag{4}$$

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System Reserve Requirement

Hourly spinning reserve requirements Rt must be met:

$$\sum_{i=1}^{N} U_i(t)\, P_{i\max} \geq Pd(t) + R^t \tag{5}$$

2.3. Unit Constraints

The generating unit operational constraints are as follows:

Generation Limits

The real power generation of each generator has a lower and upper limit so that generation should lie within this boundary. This inequality is stated as follows:

$$P_{i\min} \leq P_i(t) \leq P_{i\max} \tag{6}$$

Unit Minimum Up/Down Time Constraints

The inequality constraints of minimum up/down time limits of generating units is given by,

$$\begin{aligned} T_i^{on} &\leq X_i^{on} \\ T_i^{off} &\leq X_i^{off} \end{aligned} \tag{7}$$

III. GREY WOLF OPTIMIZER (GWO)

The GWO mimics the hunting behavior and the social hierarchy of grey wolves. The grey wolves are categorized according to societal hierarchy as alpha, beta, delta and omega. The alphas are the dominant because the group follows his/her instructions and the betas, the secondary wolves that assist the alphas in making decisions. Omega is the lowest ranking grey wolves. If a wolf is neither an alpha nor a beta, or an omega, he/she is called delta (sub-ordinate). Delta wolves come in the hierarchy next to the alphas and betas but they lead the omega. In addition to the social hierarchy of wolves, group hunting is another appealing societal action of grey wolves. The main segments of GWO are encircling, hunting and attacking the prey.

3.1. Social hierarchy

The fitness solutions are structured according to the societal hierarchy of wolves. The best fitness solution is regarded as alpha (α) followed by beta (β), delta (δ) and omega (ω) wolves.

3.2. Encircling prey

A grey wolf can update its position inside the space around the prey in any random location by using Eqs. (8) and (9).

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The encircling behavior of grey wolves can be represented as:

$$\vec{D} = \left| \vec{C}. \vec{X}_p(t) - \vec{X}(t) \right| \quad (8)$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{A}. \vec{D} \quad (9)$$

Where, the values of $\vec{A}$ and $\vec{C}$ are computed using the following equations:

$$\vec{A}. = 2\vec{a}.rand_1 - \vec{a} \quad (10)$$

$$\vec{C}. = 2.rand_2 \quad (11)$$

The components of $\vec{a}$ are linearly decreased from 2 to 0 over the course of iterations.

3.3. Hunting

The alpha, beta and delta type grey wolves have superior knowledge about the potential location of prey. Hence, the first three best solutions acquired are saved and coerce the other search agents to update their positions according to the location of the best search agents. The following equations can be used in this regard.

$$\vec{D}_\alpha = \left| \vec{C}_1. \vec{X}_\alpha - \vec{X} \right| \quad (12)$$

$$\vec{D}_\beta = \left| \vec{C}_2. \vec{X}_\beta - \vec{X} \right| \quad (13)$$

$$\vec{D}_\delta = \left| \vec{C}_3. \vec{X}_\delta - \vec{X} \right| \quad (14)$$

$$\vec{X}_1 = \vec{X}_\alpha - \vec{A}_1. (\vec{D}_\alpha) \quad (15)$$

$$\vec{X}_2 = \vec{X}_\beta - \vec{A}_2. (\vec{D}_\beta) \quad (16)$$

$$\vec{X}_3 = \vec{X}_\delta - \vec{A}_3. (\vec{D}_\delta) \quad (17)$$

$$\vec{X}(t+1) = (\vec{X}_1 + \vec{X}_2 + \vec{X}_3)/3 \quad (18)$$

3.4. Attaching the prey

In this phase, the value of $\vec{a}$ is reduced and thereby the fluctuation range of $\vec{A}$ is decreased. When $\vec{A}$ has random values in the range [-1, 1], then the search agent's next location will be in any place between its current position and the position of the prey.

3.5. Exploration

Grey wolves mostly search according to the position of the alpha, beta, and delta. They diverge from each other to search for prey and converge to attack prey. In order to mathematically model divergence, we utilize $\vec{A}$ with

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random values greater than 1 or less than -1 to oblige the search agent to diverge from the prey. This emphasizes exploration and allows the GWO algorithm to search globally.

IV. REAL CODED GREY WOLF OPTIMISATION ALGORITHM

In the UC, solution vectors are represented as integer codes of on/off schedule and the initial position consisting of a sequence of integers that represent on/off status of generating units. The operator may know the number of on/off cycles of generating units from the operational history. The daily load curve helps to determine the number of on/off cycles of the generating unit particularly for base, medium and peak load units. Generally, this number is small, the reduction of cycles of these units may restrict the search space and this may lead to sub-optimal solutions. This can be easily overcome by adopting same and equal number of cycles.

After considering the suitable Number of Cycles (NC) for the scheduling horizon, the operational duration of NC-1 cycles are randomly generated. For the first cycle operation, the initial status is considered. The typical real coded representation for one day scheduling with 'NC' cycles per day is presented in the Figure 1. The fitness function is evaluated for each solution that has terms of the total production cost over the scheduling horizon and the penalty function which penalizes the constraint violation.

Unit 1		.....		Unit 2		.....		.....			Unit N	
1	2	……	NC	1	2	……..	NC	……	1	2	……	NC
24	0	.....	0	24	0	……..	0	……	-7	3	……	-2

(a) An individual in an initial population

$$x = \begin{bmatrix} 24 & 0 & .... & 0 & : & 24 & 0 & ..... & 0 & : & ..... & ..... & : & -7 & 3 & .... & -4 \\ 24 & 0 & .... & 0 & : & 24 & 0 & ..... & 0 & : & ..... & ..... & : & -6 & 4 & ..... & -3 \\ : & : & ..... & : & : & : & : & ..... & : & : & ..... & ..... & : & : & : & : & : \\ 24 & 0 & ..... & 0 & : & 24 & 0 & ..... & 0 & : & ..... & ..... & : & -4 & 5 & ..... & -4 \end{bmatrix}$$

(b) Initial population

Figure 1 Configuration for Initial Population to UC Problem using RCGWO

V. SIMULATION RESULTS AND DISCUSSIONS

The RCGWO algorithm is developed in Matlab 7.9 platform and is executed on personal computer configured with Intel core i3 processor 2.20 GHz and 4 GB RAM. The RCGWO algorithm is applied for this work. It consists of a standard 10 unit system.

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This test system is a standard one which consists of ten generating units with 24 hours scheduling horizon. The system and generating units' data are taken from the literature Kazarlis et al., 1996. The load demand and reserve are presented in figure 2. The RCGWO algorithm is implemented and the obtained best feasible unit consignment and real power sharing among online generating units are presented in Table 1. The statistical comparison of results and execution time by RCGWO are compared with the earlier reports and is presented in the Table 2. It is incidental from Table 2, that the RCGWO method has shown outstanding performance in finding the global solution in comparison with the mathematical and heuristic approaches even when the number of units in the system is relatively large.

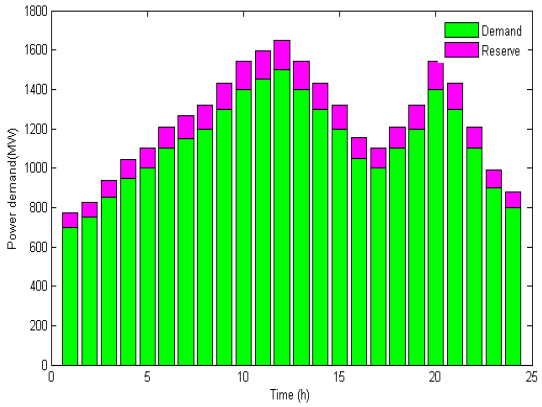

Figure 2 Power demand and reserve for 10-unit test system

Table 1 Test results of the RC-GWO for 10 unit system for 24 h.

Hour	Power output (MW)										Fuel cost ($)	Start- up cost($)
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}		
1	455	245	0	0	0	0	0	0	0	0	13 683	0
2	455	295	0	0	0	0	0	0	0	0	14 554	0
3	455	390	0	0	25	0	0	0	0	0	16 809	900
4	455	455	0	0	40	0	0	0	0	0	18 597	0
5	455	390	0	130	25	0	0	0	0	0	20 020	560
6	455	360	130	130	25	0	0	0	0	0	22 387	1100
7	455	410	130	130	25	0	0	0	0	0	23 261	0
8	455	455	130	130	30	0	0	0	0	0	24 150	0
9	455	455	130	130	15	20	25	0	0	0	27 251	860
10	455	455	130	130	162	33	25	10	0	0	30 057	60
11	455	455	130	130	162	73	25	10	10	0	31 916	60
12	455	455	130	130	162	80	25	43	10	10	33 890	60
13	455	455	130	130	162	33	25	10	0	0	30 057	0
14	455	455	130	130	85	20	25	0	0	0	27 251	0

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15	455	455	130	130	30	0	0	0	0	0	24 150	0
16	455	310	130	130	25	0	0	0	0	0	21 513	0
17	455	260	130	130	25	0	0	0	0	0	20 641	0
18	455	360	130	130	25	0	0	0	0	0	22 387	0
19	455	455	130	130	30	0	0	0	0	0	24 150	0
20	455	455	130	130	162	33	25	10	0	0	30 057	490
21	455	455	130	130	85	20	25	0	0	0	27 251	0
22	455	455	0	0	145	20	25	0	0	0	22 735	0
23	455	425	0	0	0	20	0	0	0	0	17 645	0
24	455	344	0	0	0	0	0	10	0	0	15 426	0

Total fuel cost ($) = 559845.50
Total start up cost ($) = 4090
Total operating cost ($) = 563935.50

Table 2 Statistical comparison of results and execution time for 10-unit system

Methods	Best cost ($)	Worst cost ($)	Mean cost ($)	Execution time (s)
SA	565 828	566 260	566 260	8.35
GA	563 977	565 606	564 275	221
EP	564 551	566 231	565 352	100
PSO	564 212	565 783	565 783	NA
BGSA	563937	564241	564031	NA
RC-GWO	**563 935.50**	**563 944.76**	**563 944.76**	**0.624**

VI. CONCLUSION

In this paper, a novel evolutionary algorithm known as RCGWO for solving the UC problem is proposed. The real coded implementation of problem variables handles the operational constraints easily. The RCGWO is implemented on the standard 10-unit system for solving of thermal UC problems.

The salient features of RCGWO for solving UC problems are

(i) It can consistently find good pre-dispatch schedule within a good execution time.

(ii) It can produce many different UC schedules in a single run.

(iii) Finally, the simulation results show a big improvement of the RCGWO, even though powerful methods are set as trendy over decades.

It is worthy to note that the RCGWO marks a new feasible solution for classical UC with generator outages. The successful implementation presented in this paper highlights the importance of RCGWO as a powerful tool for short term UC problems. In future, the RCGWO would be likely to be applied for solving security constrained thermal power scheduling problem

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REFERENCES

1. Wood, J., Wollenberg, B.F.: 'Power Generation Operation and Control' (Wiley, New York, 2002)
2. Kazarlis, S.A., Bakirtzis, A.G., Petridis, V.: 'A genetic algorithm solution to the unit commitment problem', IEEE Trans. Power Syst., 1996, 11, (1), pp. 83-92
3. Juste, K.A., Kita, H., Tanaka, E., Hasegawa, J.: 'An evolutionary programming solution to the unit commitment problem', IEEE Trans. Power Syst., 1999, 14, pp. 1452-1459
4. Cheng, C.P., Liu, C.W., Liu, G.C.: 'Unit commitment by Lagrangian relaxation and genetic algorithms', IEEE Trans. Power Syst., 2000, 15, (2), pp. 707-714
5. Chandrasekaran, K., Sishaj, P.S., Narayana Prasad Padhy.: 'Binary real coded firefly algorithm for solving unit commitment problem', Info. Sciences., 2013, 249, pp. 67-84
6. Xiaohui Yuan., Bin Jishuangquan Zhang., HaoTian., Yanhong Hou.: 'A new approach for unit commitment problem via binary gravitational search algorithm', Appl. Soft Comput., 2014, pp. 249-260
7. Wu, Z., Chow, T.: 'Binary neighbourhood field optimization for unit commitment problems', IET Gener. Transm. Distrib., 2013, 7(3), pp. 298-308
8. Mohammad Barati., Malihe M. Farsangi.: 'Solving unit commitment problem by a binary shuffled frog leaping algorithm', IET Gener. Transm. Distrib., 2014, 8,(6), pp. 1050-1060
9. Marian Marcoveccio, G., Augusto Novals, Q., Ignacio Grossmann, E.: 'Deterministic optimization of the thermal unit commitment problem: A branch and cut search', Computer and Chemical Engg., 2014, 67, pp. 53-68
10. Dewan Fayzur Rahman., Ana Viana., Joao Pedro Pedroso.: 'Metaheuristic search based methods for unit commitment', Electr. Power Energy Syst., 2014, 59, pp. 14-22
11. Ran Quan., Jinbao Jian., Linfeng Yang.: 'An improved priority list and neighborhood search method for unit commitment', Electr. Power Energy Syst., 2015, 67, pp. 278-28
12. Lingfeng Wang., Chanan Singh.: 'Unit commitment considering generator outages through a mixed integer particle swarm optimization algorithm', Appl. Soft Comput., 2009, 9, pp. 947-953
13. Mirjalili, S., Mirjalili, S.M., Lewis, A.: 'Grey wolf optimizer', Adv. Eng. Soft., 2014, 69, pp. 46-61

Nomenclature

ai, bi, ci	cost coefficients of generating unit i
di, ei, fi	emission coefficients of generating unit i
N	number of generators
T	total scheduling period
Pimax	maximum real power generation limit of unit i in MW
Pimin	minimum real power generation limit of unit i in MW
D(t)	system load demand in the hour t in MW
Xioff(t)	duration during which unit i is continuously off
SCi(t)	start up cost of unit i at hour t in $
SDi(t)	shut down cost of unit i at hour t in $
Fi(Pi(t))	fuel cost of unit i at hour t in $/h
Ft	total cost in $
h-costi	hot start cost of unit i in $
c-costi	cold start cost of unit i in $
c-s-houri	cold start time of unit i
Pd(t)	load demand at hour t in MW