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A New Approach for GENCOs Profit Based Unit Commitment in Electricity Market

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ABSTRACT
In restructured power systems, planning unit commitment includes optimization of production sources in order to maximize the profit of power producing corporations (GENCO) with conforming to the related limits, which is introduced as the planning based on the profit of units commitment (PBUC). In this paper, the algorithm of Iteration Particle Swarm Optimization (IPSO) has been used in order to solve the problem of PBUC. The performance of the Classical Particle Swarm Optimization (CPSO) greatly depends on its parameters, and it often suffers the problem of being trapped in local optima. A new index named, Iteration Best, is incorporated in CPSO to enrich the searching behavior, solution quality and to avoid being trapped into local optimum. A new index named, Iteration Best, is incorporated in CPSO to enrich the searching behavior, solution quality and to avoid being trapped into local optimum. In this paper, a ten-unit power generation system has been used in order to solve the problem of PBUC. Comparison between the best conclusions achieved in this research and the best ones reported in the literature of this subject reveals the excellence of the procedure used in this research.
Keyword: Profit Based Unit Commitment (PBUC), Restructured Power Systems, Iteration Particle Swarm Optimization (IPSO).

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INTRODUCTION

In power systems with traditional structures, units commitment planning is considered as optimization of power-producing units in order to meet the demands with the lowest prices. In minimizing the costs of utilization, units commitment based on its costs is usually referred [1]. Recently, most of the electrical power industries are changing from integrated vertical structure to private structure, which is referred as restructuring. It means breaking integrated vertical power systems up into producing, conveyance, and distribution corporations [2]. The fundamental purpose of privatization is to create a competitive situation among the producers and provision of lower prices for Consumers to choose [2]. This has been resulted into a change in procedures to solve the problems of the new situation.

Nowadays, there is no guarantee to have just one corporation to supply electricity, so predicting the corporations' (GENCO) share of demands for electricity is more difficult than ever. Sequentially, as the aim of GENCO is to maximize their profit, units' commitment (UC) problem must be dealt differently and with PBUC. In PBUC, power provision is not compulsory, and maximizing the profit is the aim. However, in traditional UN, the producing corporations are planned in a way that demands are met with the lower prices [2]. In comparison with UC, the outstanding feature of PBUC is that all the market information is reflected in the price, and so thermal units, combined and water cycle, and pump reserve are provided and MIP and LR methods are compared. In addition, combined methods, for example LR and GA [3], LR and Evolutionary planning [4], and DP and non-linear planning as an innovative method [5] are used to solve the problem of PBUC. An arbitrary planning method considering uncertainty in demands and market prices has been introduced [6]. In [7], the solution of the problem PBUC in a momentary market has been used with an arbitrary DP, in which power uncertainty and availability of producing units have been considered. In research [8], a revolutionary method based on priority has been introduced. In research [9], separate binary PSO algorithm has been used to solve the problem PBUC. Research [10], in

order to guarantee market stability, solves the problem PBUC with a reinforced pricing method and implementing GA has been offered. Modeling market prices uncertainty and sequential financial risks, research [11] presents a linear arbitrary mixed program of round number to solve the problem PBUC. Research [12], in order to solve PBUC in a market, has predicted the production probability of circulating and non-circulating reserves using artificial neural networks. [17]
In this paper, in order to solve the problem PBUC, IPSO algorithm searches the optimum response with an initial arbitrary population, in which allowed limits of variables are considered. In part II, PBUC formulation is presented. An introduction to IPSO algorithm, and simulation conclusions and algorithm implementation in a ten-unit thermal power system are presented respectively in part III and IV.

Formulation of PBUC

PBUC problem is one of the important problems of optimization in restructuring situation. The most important aim is allocating producing units in order to maximize GENCO profit. This problem is solved in accordance with the predicted price and demand. In mathematics, PBUC is formulated as below.

The Objective Function

The objective function is defined as formula (1) [2],

$$Max\ PF = RV - TC \quad (1)$$

$$RV = \sum_{t=1}^{T}\sum_{i=1}^{N} P(i,t).\Pr(t)X(i,t) \quad (2)$$

$$TC = \sum_{t=1}^{T}\sum_{i=1}^{N}\{F(P(i,t))X(i,t) + SU(i,t)X(i,t)\} \quad (3)$$

and setup costs as below [2].

$$F(P(i,t)) = a_i(P(i,t))^2 + b_i(P(i,t)) + c_i \quad (4)$$

$$SU(i,t) = \begin{cases} CSC(i) \\ if \quad T^{OFF}(i,t) \le CST(i) + MDT(i) \\ HSC(i) \\ if \quad T^{OFF}(i,t) > CST(i) + MDT(i) \end{cases} \quad (5)$$

$$X(i,t) = \begin{cases} 0 & Unit\ i\ is\ Off \\ 1 & Unit\ i\ is\ On \end{cases} \quad (6)$$

Limits

Power demand limits, circulating reserve, units' production capacity, and the units' minimum period of being on and off are considered as below.

The Limits of the System

1. Power demand limits [2]

$$\sum_{i=1}^{N}\{P(i,t)X(i,t)\} \le P_D(t), \quad t = 1,2,\dots,T \quad (7)$$

2. Circulating reserve limits [2]

$$\sum_{i=1}^{N}\{SR(i,t)X(i,t)\} \le SR(t), \quad t = 1,2,\dots,T \quad (8)$$

$$SR(t) = \sum_{i=1}^{N} P_{max}(i) - P_D(t) \quad (9)$$

2. 2. The Function of the Limits

1. Production capacity limits [2]

$$P_{min}(i) \le P(i,t) \le P_{max}(i), \quad t = 1,2,\dots,T \quad (10)$$

2. The minimum period of being on [2]

$$T_{on}(i,t) > MUT(i) \quad (11)$$

3. The minimum period of being off [2]

$$T_{off}(i,t) > MDT(i) \quad (12)$$

IPSO algorithm

1. Classical Particle Swarm Optimization

PSO is an optimizing technic based on Laws of probability, which has been presented by DR. Russell Eberhart and Dr. James candy in 1995. It has been inspired by birds and fish's social behavior [13, 14]. It is assumed that a group of birds in an area search accidentally for food; however, there is food in just one place of the area. They are not aware of the place of the food and they just know the distance to the food. The strategy is that the birds follow the bird which has the closest distance to the food [13]. In PSO, each answer to the problem is a bird in the searching aria, which is called a particle. Each particle has an extent of competence which is defined by competence function. The closer to food a bird is, the more competent it is.

The PSO starts with a population of random solutions "particles" in a D-dimension space. The *i*th particle is represented by $X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})$. Each particle keeps track of its coordinates in hyperspace, which are associated with the fittest solution it has achieved so far. The value of the fitness for particle *i* (pbest) is also stored as $P_i = (p_{i1}, p_{i2}, \ldots, p_{iD})$. The global version of the PSO keeps track of the overall best value (gbest), and its location, obtained thus far by any particle in the population. PSO consists of, at each step, changing the velocity of each particle toward its pbest and gbest according to Eq. (13). The velocity of particle *i* is represented as $V_i = (v_{i1}, v_{i2} \ldots v_{iD})$.
Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward pbest and gbest. The position of the *i*th particle is then updated according to Eq.(14)

$$v_{id} = w \times v_{id} + c_1 \times rand() \times (P_{id} - x_{id}) + c_2 \times rand() \times (P_{gd} - x_{id}) \quad (13)$$

$$x_{id} = x_{id} + c\, v_{id} \quad (14)$$

Where, P_{id} and P_{gd} are *pbest* and *gbest*. The positive constants c1 and c_2 are the cognitive and social components that are the acceleration constants responsible for varying the particle velocity towards *pbest* and *gbest*, respectively. Variables r_1 and r_2 are two random functions based on uniform probability distribution functions in the range [0, 1]. The use of variable *w* is responsible for dynamically adjusting the velocity of the particles, so it is responsible for balancing between local and global searches, hence requiring less iteration for the algorithm to converge [15]. The following weighting function *w* is used in Eq. (13):

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter\_max} iteration \quad (15)$$

Where, *iter_max* is the maximum number of iterations and *iteration* is the current number of iteration. The Eq. (15) presents how the inertia weight is updated, considering w_{max} and w_{min} are the initial and final weights, respectively.

Iteration Particle Swarm Optimization
In this paper, a new index named, Iteration Best, is incorporated in Eq. (13) to enrich the searching behavior, solution quality and to avoid being trapped into local optimum, IPSO technique is proposed, Eq. (16) shows the new form of Eq. (13):

$$v_{id} = w \times v_{id} + c_1 \times rand() \times (P_{id} - x_{id}) + c_2 \times rand() \times (P_{gd} - x_{id}) + c_3 \times rand() \times (I_b - x_{id}) \quad (16)$$

Where, I_b is the best value of the fitness function that has been obtained by any particle in any iteration and c_3 shows the weighting of the stochastic acceleration terms that pull each particle toward I_b.

CONCLUSIONS
In this paper, the problem of PBUC is solved with IPSO algorithm. The initial optimum population includes an arbitrary population with the optimum productivity capacity of the units in a way that for each unit it equals P of the unit and for P(i), the amount of RC(i) is maximum.
Additionally, the second method utilized in this research, in comparison with the conclusions reported in this literature, is of an outstanding excellence. In this research, a ten-unit power producing system has been used in order to solve the problem PBUC. Specifications of the ten-unit power producing system, and Specifications of power demands and prices are respectively presented in tables 1 and 2. And the conclusions of the solution to the problem IPSO is presented in table 3.
Table 4 presents the final solution to PBUC using IPSO algorithm with considering initial optimum population in order to start searching. Table 5 presents the comparison of the best conclusions of this research with the best reported conclusions in this literature, which reveals the excellence of the used method.

Table1. Specifications of the ten-unit electrical power producing system

Units	P_{min}	P_{max}	a_i	b_i	c_i	MUT	MDT	HSC	CSC	CST	IS
1	150	455	0.00048	16.19	1000	8	8	4500	9000	5	8
2	150	455	0.00031	17.26	970	8	8	5000	10000	5	8
3	20	130	0.00200	16.60	700	5	5	550	1100	4	-5
4	20	130	0.00211	16.50	680	5	5	560	1120	4	-5
5	25	162	0.00398	19.70	450	6	6	900	1800	4	-6
6	20	80	0.00712	22.26	370	3	3	170	340	2	-3
7	25	85	0.00079	27.74	480	3	3	260	520	2	-3
8	10	55	0.00413	25.92	660	1	1	30	60	0	-1
9	10	55	0.00222	27.27	665	1	1	30	60	0	-1
10	10	55	0.00173	27.79	670	1	1	30	60	0	-1

Table2. Specifications of price and demand of produced power within 24 hours a day

hour	Demand(MW)	Price($)	hour	Demand(MW)	Price($)
1	700	22.15	13	1400	24.60
2	750	22.00	14	1300	24.50
3	850	23.10	15	1200	22.50
4	950	22.65	16	1050	22.30
5	1000	23.25	17	1000	22.25
6	1100	22.95	18	1100	22.05
7	1150	22.50	19	1200	22.20
8	1200	22.15	20	1400	22.65
9	1300	22.80	21	1300	23.10
10	1400	29.35	22	1100	22.95
11	1450	30.15	23	900	22.75
12	1500	31.65	24	800	22.55

Table3. Comparison of the best conclusions of the algorithm

Algorithms	Generation	Best profit
CPSO	500	102246
IPSO	500	103327

Table4. The final solution of the problem PBUC, productivity capacity in MW scale

Hour	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)
1	382	318	0	0	0	0	0	0	0	0
2	390	359	0	0	0	0	0	0	0	0
3	440	408	0	0	0	0	0	0	0	0
4	453	455	0	0	0	0	0	0	0	0
5	455	455	0	0	0	0	0	0	0	0
6	455	455	0	140	0	0	0	0	0	0
7	455	455	0	130	0	0	0	0	0	0
8	436	455	0	140	0	0	0	0	0	0
9	434	448	129	130	160	0	0	0	0	0
10	451	455	126	129	160	77	0	0	0	0
11	455	451	140	140	174	85	0	0	0	0
12	455	455	150	136	187	91	0	0	0	0
13	453	447	143	134	178	0	0	0	0	0
14	445	455	128	126	158	0	0	0	0	0
15	433	388	134	134	0	0	0	0	0	0
16	389	389	112	115	0	0	0	0	0	0
17	408	423	107	114	0	0	0	0	0	0
18	434	455	120	121	0	0	0	0	0	0
19	455	455	134	134	0	0	0	0	0	0
20	455	455	160	160	0	0	0	0	0	0
21	455	421	147	160	0	0	0	0	0	0
22	422	392	128	128	0	0	0	0	0	0
23	404	427	103	0	0	0	0	0	0	0
24	285	375	88	0	0	0	0	0	0	0

Table5. Comparison of the total profit of the ten-unit electrical power producing system

Algorithms	Profit ($)
TS-IRP	103261
GA	101086
CPSO	102246
IPSO	103327

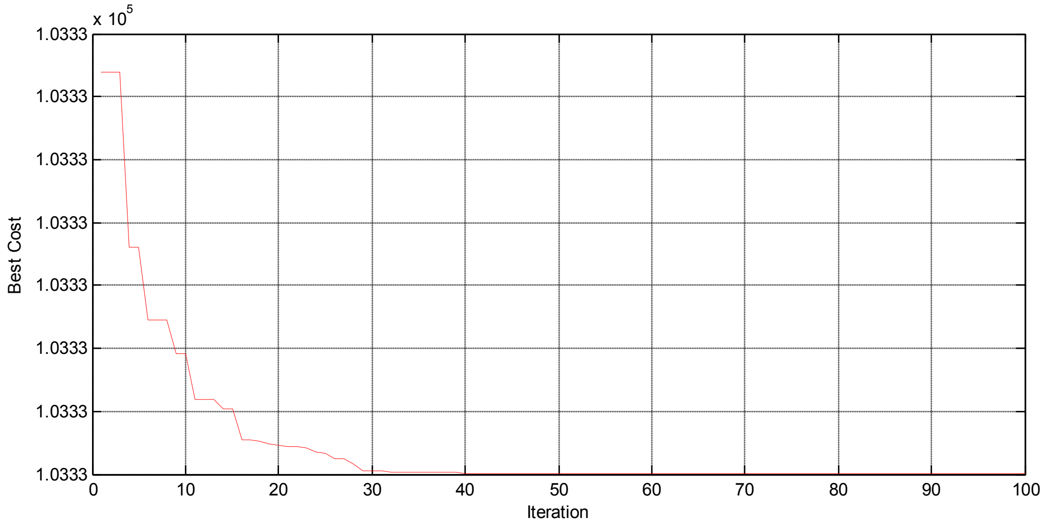

Figure 1. Best cost by iteration curve

ai, bi, ci	Fuel cost function coefficients of *i*th thermal units
Cstart	Setup cost function of thermal unit
csc	Setup cost of thermal unit in a cold condition
c(i,t)	Cost of *i*th thermal unit within *t*th period
c_1, c_2	Acceleration coefficients in order to update speed of a particle
DP	Dynamic planning
ε	Tolerance
$F(P_i,t))$	Fuel cost function of *i*th thermal unit within *t*th period
GA	Genetic algorithm
GENCO	Power producing corporation
G	The total number of the involved thermal units
G_{best}	The most competent amongst all the particles
HSC	Setup cost of thermal unit in a hot condition
I	Thermal unit index
IS	Initial condition
J	Index of the thermal units involved in productivity
k	Number of variables of optimization problem in PSO
LR	Lakranzhy release
MCP	Market final price
MDT(i)	The minimum off period of the *i*th thermal unit
MIP	Mixed programming of round number
MUT(i)	The minimum period of being on of the *i*th thermal unit
N	The total number of thermal units
n	Number of particles of a population
PSO	Particle swarm optimization
P(i,t)	Output capacity of the *i*th thermal unit within *t*th period
$P_{max}(i)$	Maximum output capacity of the *i*th thermal unit
$P_{min}(i)$	Minimum output capacity of the *i*th thermal unit
$P_D(i)$	Power demand within *i*th period
PF	GENCO profit
Pr(t)	Market price within *t*th period
P_best	The most competent particle
RC(P(i))	The ratio of income of *i*th unit to its cost
V_{id}	The speed after *d*th from *i*th particle
V_{max}	The maximum speed of a particle
w	Inertia weight
X	The initial population
X_{id}	The position after *d*th from *i*th particle

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