Fast Security Constraint Unit Commitment by Utilizing Chaotic Crow Search Algorithm

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Abstract— **This paper investigates the optimal operation of security constraint unit commitment (SCUC) as one of the most important concern in power system operation. SCUC is a mixed integer nonlinear problem (MINLP) which is hard to solve and also the optimal solution is not guarantee. To overcome this drawback, a new evolutionary method known as the chaotic crow search algorithm is developed. The proposed problem includes some significant constraints such as spinning reserve, generators ramp rate, load balance, and power limits. Finally, the proposed method is examined on a 10-unit distribution network. The results show the effectiveness and merit of the proposed technique.**

Index Terms— **Control and Optimization, Evolutionary Algorithm, Power systems, Reliability, Unit Commitment**

I. INTRODUCTION

Unit commit is an optimization problem which tries to find a solution to determine which units should be working or shut down during the operation time. Based on the assumptions, three types of problems will be defining: 1) Security Constrained Unit Commitment (SCUC) 2) Profit Based Unit Commitment (PBUC) 3) Cost Based Unit Commitment (CBUC).

In this research studies, cost based unit commitment is analyzed and tries to minimize the cost function. As a result, solving this problem required to consider two sub problems at the same time: a) the economic dispatch b) determine the on and off status of every unit at every horizon intervals time. In the recent years, many papers have been released to satisfy the first and second points [1] such as dynamic programming (DP) [2], [3], particle swarm optimization (PSO) [4-5-6-7], genetic algorithm (GA) [8-9-10], etc. These papers tried to minimize the cost function or maximized the profit of the unit commitment [11-21]. On the other hand, the availability of the electricity is the main goal of the unit commitment. It should be mention that; the availability should be equal to the demand because there is no way to storage the electricity [22-29]. Therefore, the unit commitment should be design so that the generating units provide enough electricity for every interval schedule time with a minimum cost [30-37].

In this research study, minimizing the cost function of the unit commitment with high preference is improved by Teaching Learning Based Optimization (TLBO) method as a new evolutionary algorithm. All of the constraints problems associated with unit commitment is considered for this research study. Moreover, the generating cost of the unit commitment by TLBO has been compared with other methods in the same conditions. The results proved the better performance of the TLBO.

II. CONSTRAINTS OF UNIT COMMITMENT

A. Objective Function

The total cost function of the unit commitment is the total summation of fuel cost and start-up cost which is defined as following:

$$min \quad TC = \sum_{t=1}^{M}\sum_{i=1}^{N} FC_i^t \; + SDU_i^t \qquad (1)$$

Where, TC is the total cost, N represents the unit number, FC is the fuel cost of the ith unit at time t and SU is the start-up cost of the ith unit at time t. This total cost can be effected by some constraints in unit commitment problem. The constraints are explained by the next sub sections [38-40].

Table 1: Prediction of load demand for 24 hours

Hour[h]	1	2	3	4	5	6	7	8
Demand [MW]	700	750	850	950	1000	1100	1150	1200
Hour[h]	9	10	11	12	13	14	15	16
Demand [MW]	1300	1400	1450	1500	1400	1300	1200	1050
Hour[h]	17	18	19	20	21	22	23	24
Demand [MW]	1000	1100	1200	1400	1300	1100	900	800

B. *Constraints*

- ***Load Demand***

There is no way to storage the electrical energy. As a result, the generation's power should be equal to the load demand [42-45]:

$$\sum_{i=1}^{N} P_i^t . U_i^t = H^t \qquad (2)$$

According to the equation two, the load demand at time t is equal to H^t, where U_i^t represents the unit number and P_i^t is

its related power at time t. Therefore, the summation of all the power generations should be equal to H^t.
It should be noted that the number of units in this case of study are 10 units and the load prediction is defined for 24 hours (or a day) schedule time. Table 1 shows the Prediction of load demand for 24 hours [46-47].

- **Power Bounded**

Every unit has a limitation in power generation based on its design. Indeed, every unit has a maximum and minimum potential for power generation and it is impossible to generate the power more than its capability. On the other hand, it is not affordable to generate the power less than its minimum power. This limitation can be taken into account by equation (3):

$$P_{i,\min} \prec P_i^t \prec P_{i,\max} \tag{3}$$

Where $P_{i,\min}$ represents the minimum power of ith unit and $P_{i,\max}$ represents the maximum power of ith unit.

2.1 Increase and decrease the power

Every unit has a limitation in increasing or decreasing its power rapidly. In fact, every unit can change its power according to a specific rate which is defined based on its design. This limitation can be taken into account by equation (4):

2.2 Start-up Constrains

$$(P_i^{t-1} - RD_i) \prec P_i^t \prec (P_i^{t-1} - RU_i) \tag{4}$$

Where RD_i and RU_i are hourly rate reduction and increase for ith unit respectively.
The most important part in the ensure voltage availability analysis of the unit commitment is spinning reservation. In many cases this constraint is not consider to solve the unit commitment easily. Although, this constrain plays a very significant role in the reliability of the system. In this research study, spinning reservation is applied in order to increase the reliability of the system and also warrantee the availability of the voltage with a very high probability. This constraint is given in equation (7) and (8):

$$SR_{up}^t = \sum_{i=1}^{N} \min(P_{i,\max} - P_i^t, M \times r_i).U_i^t \tag{7}$$

$$SR_{dn}^t = \sum_{i=1}^{N} \min(P_i^t - P_{i,\min}, M \times r_i).U_i^t \tag{8}$$

Where SR_{up} represents spinning reservation when the load demand increase and SR_{dn} represents spinning reservation when the load demand is decrease. Moreover, r is the coefficient of the ramp rate which is considered equal to 10 in this study. It means that ramp rate can change within 10 minutes. The assumption of the unit commitment problem shows in table 2.

Table 2. Unit commitment assumptions

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
a_i	1000	970	700	680	450	370	480	660	665	670
b_i	19.16	17.26	16.6	16.5	19.7	22.26	27.4	25.92	27.27	27.79
C_i	0.00048	0.00031	0.002	0.00211	0.00398	0.00712	0.00079	0.00413	0.00222	0.00173
P_{max}	455	455	130	130	162	80	85	55	55	55
P_{min}	150	150	20	20	25	20	25	10	10	10
r	9.1	9.1	2.6	2.6	3.24	1.6	1.7	1.1	1.1	1.1
RU	227.5	227.5	65	65	81	40	42.5	27.5	27.5	27.5
RD	227.5	227.5	65	65	81	40	42.5	27.5	27.5	27.5
T_{ON}	8	8	5	5	6	3	3	1	1	1
T_{OFF}	8	8	5	5	6	3	3	1	1	1
T_{cold}	5	5	4	4	4	2	2	0	0	0
SU_{cold}	9000	1000	1100	1120	1800	340	520	60	60	60
SU_{hot}	4500	5000	550	560	900	170	260	30	30	30
In.State	8	8	-5	-5	-6	-3	-3	-1	-1	-1

According to the equation (1), start-up cost has a significant influence in the total cost. In the unit commitment two types of start-up cost is defined: 1) Hot Start-up: when the unit is not cool down completely and needs to start-up again. 2) Cold Start-up: when the unit is cool down completely.
This limitation can be taken into account by equation:

$$St_i = \sum_{k=t-T_i^{off}-T_i^{cold}}^{t-1} U_i^k .SU_i^t \tag{5}$$

Where,

$$SU_i^t = \begin{cases} SU_i^{hot}.U_i^t.(1-U_i^{t-1}) & \text{if } St_i^t \succ o \\ SU_i^{hot}.U_i^t & \text{if } St_i^t \equiv o \end{cases} \tag{6}$$

2.3 Spinning Reservation

Sometimes load demand for the electricity increase rapidly because of some reasons (for example it is a game and many people want to turn on their TV at the same time or any problem in a unit or units) which is not predicted. In this situation, the unit commitment should be able to responsible for more load demand by a reservation. On the other hand, some times the generation load is higher than the prediction. In this situation, unit commitment should be able to decrease its power generation rapidly to minimize

III. Chaotic Crow Search Algorithm

Security constraint unit commitment is a mixed integer nonlinear programming (MINLP) problem which is hard to solve and also the optimal value is not guarantee. Hence, in this research paper, a new evolutionary algorithm known as the chaotic crow search algorithm is developed to address these drawbacks. The main concept of this algorithm inspire from the crow search apparatus for hiding their food. More detail regarding this algorithm can be found in [11]. Figure 1 shows the flowchart of the proposed method.

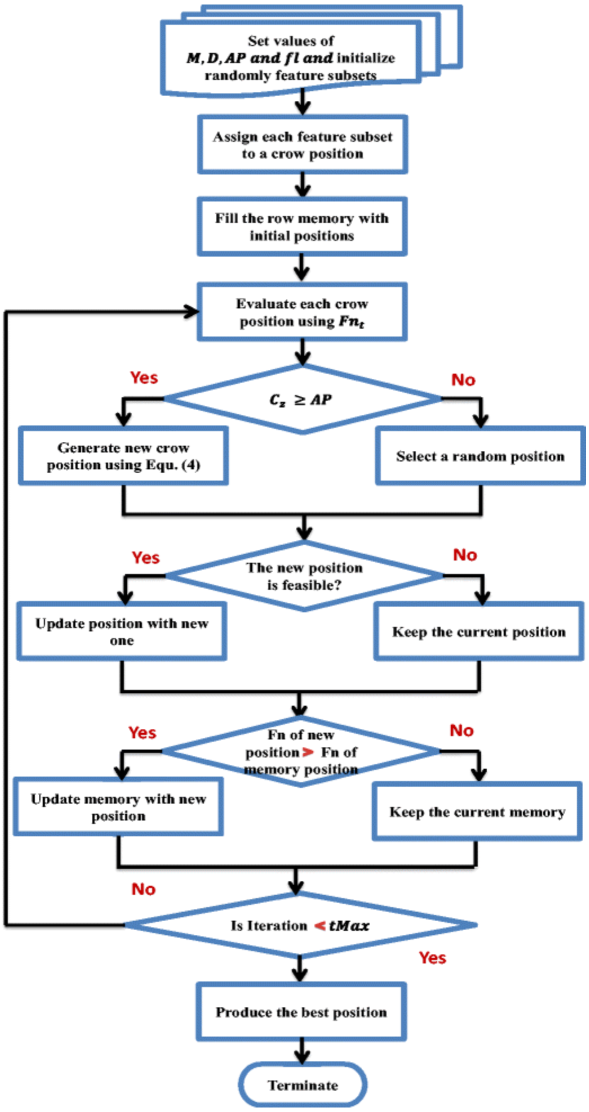

Fig. 1. Flowchart of the proposed method [11].

IV. Simulation and Results

A system including ten generation units has been considered as a test system. The load demand prediction has been considered for the day-ahead (next 24 hours). Table 2 depicts the performance of the proposed method and particle swarm optimization (PSO) algorithm. Based on the table, the performance of the proposed method is more acceptable of the well-known PSO method. Indeed, the proposed method performance is higher than PSO from both computational time and cost.

One of the most important aspect of the SCUC is considering the spinning reserve for the emergency conditions such as load fluctuation or generator outages. Fig. 2 shows the constant spinning reserve. Considering a constant spinning reserve can potentially lead to higher cost. Hence, in this paper, a dynamic spinning reserve has been considered as shown in Fig. 3. As far as it can be seen, the spinning reserve has a dynamic behavior; that means the spinning reserve values change in any interval based on the requested demand. As mentioned considering the dynamic spinning reserve can contribute to lower cost. The total operation cost of this scenario is $563827.7.

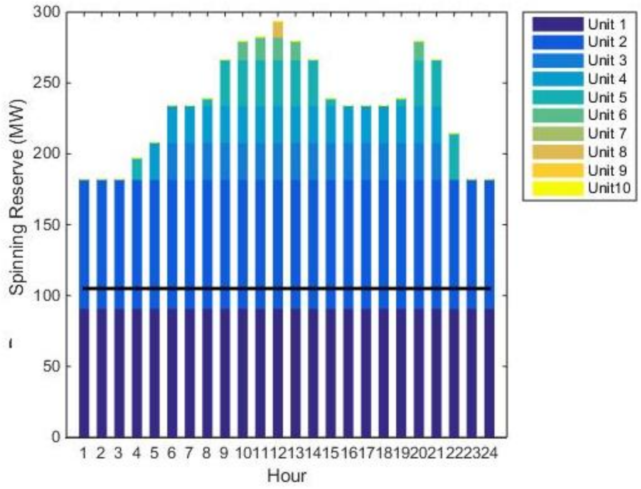

Fig. 2. Constant spinning reserve.

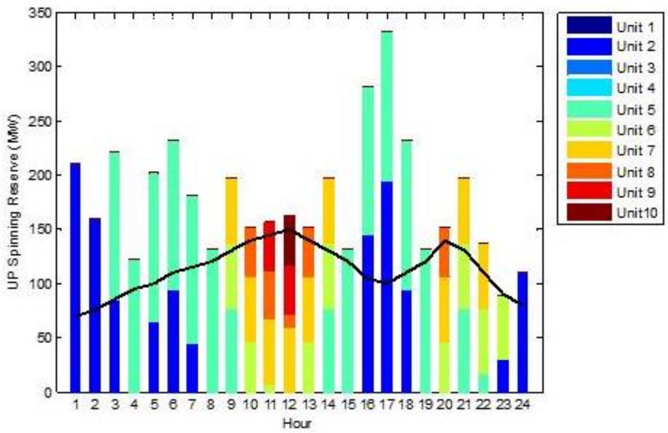

Fig. 3. Dynamic spinning reserve.

Table 2: Comparison of applied methods

Methods	Difference Between Methods			
	Start-up Cost	Fuel Cost	Final Cost	Time
PSO	4090	559852.3	563942.2	85
Proposed method	4090	559847.7	563937.7	35

V. Conclusion

In this study, TLBO is applied for 10 unit commitment problem. The results proved the better performance of TLBO compare to other evolutionary algorithms from both economic and time perspectives. Moreover, the spinning reservation of the system is analyzed which confirmed the high reliability of TLBO which contribute to high probability and availability of the electricity. TLBO is a new algorithm with a less mathematical calculation and fluent concept which can be used in the future in many optimization problems such as smart grids, renewable energy and cyber-physical systems.

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