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Solving Security Constrained Unit Commitment by Particle Swarm Optimization

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Abstract

The issue of unit commitment is one of the most important economic plans in power system. In modern and traditional power systems, in addition to being economical of the planning, the issue of security in unit operation is also of great importance. Hence power system operation confronts units' participation and input considering network security constrains. The issue of units' participation is defined as an optimization problem aimed at determining units' on or off condition and optimized level of units' production.

Keywords: particle swarm optimization, unit commitment, security-constrained unit commitment, SCUC

1- Introduction

In power system operation we always confront the issue of which production unit and how long it is at off mode. There are different ways for providing demanded load, but it is suggested to use the best operation method due to economic issues. In other words, one of the most important criteria in power systems operation is providing demanded load with lowest cost and with using optimal combination of power. Paying attention to the issue of economic hierarchy of thermal units entrance and exit not only reduces production costs, but also results in appropriate operation of networks with on time entrance and exit of units. This prevents quick depression of equipment, bearing considerable economic saving at long term [1]. This issue was developed for the first time by Loury using dynamic planning in 1966. Fundamentally, the most accurate method to solve the problem is enumeration method in a way that, during testing all possible combinations of units at studied time intervals, all combinations will be feasible. Considering modern processors' speed, solving this issue seems impossible. Hence it seems necessary to implement an appropriate algorithm [2]. Unit commitment can be introduced as a complicated decision making process. Due to having no confidence in production units' demand, stop and drop the question arises that: how we should cope with the issue of UC, when load demand or other variables are not accurate. Researchers have found that random models work better than other models under such conditions, but these models have their own limitations [3].

2- Problem Solution of Powers' Unit Commitment

UC is a strategic option to determine which one of available power plants can meet our needs. To take a power plant into account, it estimates parameters both technologically (including minimum operating, minimum time of on and off modes and transient behaviors) and economically (such as operating costs). In fact solving the problem of UC enables these power plants to minimize electrical energy production costs.

3- Unit Commitment Formulation

In fact the problem refers to minimizing target function (F) which involves several sections such as total production costs, costs of turning generator on and off, … for all production units in given time intervals and constrains such as cost of turning on and off, minimum time of switching on and off, transmission capacity limits, line losses, … applied to it. Cost of electricity power production $F_{i,k}\left(P_{i,k}\right)$ from ith production unit at period kth is always obtained with quadratic functions as follows:

$$F_{i,k}(P_{i,k})= (a_i + b_i.P_{i,k} + c_i.P_{i,k}^2)\, V_{i,k} \qquad (1)$$

Where a_i, $b_i$and c_i are coefficients of ith generator costs, $P_{i,k}$ is power produced by ith generator at period kth and $V_{i,k}$is on and off mode of ith generator at kth period. $F_{i,k}^{up}$is the cost of being switched on, and $F_{i,k}^{down}$ is the cost of being switched off which is obtained as follows for ith production unit at kth time interval. Hence we would have:

$$F_{i,k}^{up} = s_i^{up}\, v_{i,k}(v_{i,k} - v_{i,k-1}) \qquad (2)$$

$$F_{i,k}^{down} = s_i^{down}\, v_{i,k}(v_{i,k-1} - v_{i,k}) \qquad (3)$$

Where s_i^{up} shows the cost of being switched on in ith generator, and s_i^{down} is the cost of being switched off in ith generator.

Hence target function is as follows:

$$\text{F}= \sum_{i=1}^{n}\sum_{k=1}^{t}(F_{i,k}\left(p_{i,k}\right) + F_{i,k}^{up} + F_{i,k}^{down}) \qquad (4)$$

Where, n is the number of production units and t is total number of hours at studied period.

Minimum time of being switched on: whenever a production unit is switched on, it can be switched off only when a specific time has been elapsed from start time with minimum time of being switched on.

Hence we have:

$$v_{i,k} = \forall\, 0 \leq v_{i,k}^{up} \leq mup(i) \qquad (5)$$

Where, mup(i) is minimum time of being switched on of ith generator and $v_{i,k}^{up}$ is minimum time of being switched on for ith generator.

Minimum time of being switched off: whenever a production unit is turned off it can return to circuit only when a time called minimum time of being switched off elapses from the time of being switched off, so we have:

$$v_{i,k} = 0 \quad \forall \; 0 \leq \; v_{i,k}^{down} \leq mdown(i) \qquad (6)$$

Where, mdown (i) is minimum time of turning down for ith generator and $v_{i,k}^{down}$ is minimum time of turning down for generator i.

Demanded load:

$$\sum_{i=1}^{n} p_{i,k} - p_k^D - p_k^L = 0 \qquad (7)$$

Where, $p_{i,k}$ is power produced by ith generator at period k, p_k^D is demand amount at period k, and $p_k^L$is line losses at the same period.

Capacity limit of production units: power production of each generator should be between minimum production limits (p_{min}) and maximum production limits (p_{max}).

$$p_{min.i} \leq \; p_i \; \leq \; p_{max.i} \qquad (8)$$

Particle Swarm Optimization Algorithm:

Particle swarm optimization algorithm is a probability rules-based optimization technic which was first introduced by Russell C. Eberhart, a scientist in computer sciences, and James Kennedy (PhD) in 1995. In this algorithm the swarm behavior of group of birds or fishes is used while searching for food in order to lead the group toward a promising region in searching area. Birds search for food only by adjusting their physical movements through avoiding crash. Theoretically, every bird uses earlier experience of other members in the group. Such participation has an absolute advantage for finding food and the main foundation of particles' swarm algorithm relies on such division of information among group members [4]

4- Results

SCUC is different from UC solution without taking network security constrains into account. In classic problem solution of power plant unit commitment it is sufficient to meet needed load of the network at every time, in a way that none of constrains of the network is violated. Meanwhile, when network security constrains are considered, it is necessary to take into account constrains of the network. In other words, all buses' voltage along with current passed from all lines of the network should be at permitted limit. Hence, when solving underlying problem with considering security constrains, it is necessary not to violate all modes of placing power plant in the circuit constrains related to load dispatch. To achieve this goal, unlike classic problem of power plant commitment which needs economic load dispatch at all times, we need to have optimal load dispatch at all hours. Binary particle swarm algorithm is used to find the best on and off mode for power plant. Bat the algorithm is used to do optimal power flow. The following parameters in table (1) are used in binary particles swarm algorithm, and parameters in table (2), are used in optimal power solution.

Table 1- Parameters of binary particles swarm algorithm

Number of particles	**Maximum frequency**	**Inertia coefficient (W)**	**Learning coefficient of group (C2)**	**Individual learning coefficient (C1)**
50	500	0.7298	1.4962	1.4962

Table 2- Parameters of optimal power flow solution

Number of bats	**Maximum number**	**α**	**γ**	**A**	r_0	f_{max}	f_{min}
50	100	0.75	0.04	0.5	0.5	2	0.1

To show efficiency of the proposed algorithm, the method mentioned above was tested on 6-bus and 30-bus IEEE networks. Moreover, to show effects of network security constrains on total costs, the obtained results were compared to results of power plant classic unit commitment and also they were compared with results of a valid scientific reference.

4-1- Results obtained for IEEE 6-Bus Network

In this section the planning interval for powerhouse was considered 24 hours. In this planning power plant 1 is considered as the main powerhouse of the network throughout planning in the circuit.

4-1-1- Problem Solution of Power Plant Unit Commitment for 6-Bus Network without Considering Security Constrains:

In this section, planning of 6-bus network powerhouses is presented without considering security constrains, being compared with similar results in Ref [5]. In this table, 0 means powerhouse is off and 1 means powerhouse is on. According to tables 3 and 4, it can be concluded that total costs of planning period were better than results obtained from Ref(5). According to table 3, it can be seen that implemented algorithm has observed well all constrains of minimum time of being off and on in the powerhouse.

4-1-2- Problem Solution of Power Plant Unit Commitment for 6-Bus Network with Considering Security Constrains:

In this section, the aim of unit commitment of powerhouse is not mere load provision for the network, rather network lines' loses and constrains of the network should also be considered. When underlying problem is solved without considering network conditions, a non-optimal answer will be obtained. According to table 5, cost of powerhouse unit commitment is 83351.16$. Comparing this amount with cost of powerhouse commitment without considering network security constrains, 82892.8$, it can be seen that the cost increases about 450$ and this increase is assigned to addition of network security constrains to the problem. To prevent exit of amounts of buses voltage and lines power out of permitted amount, it is necessary to place costly power houses in the circuit instead of cheap powerhouses which increase operating costs in the powerhouse. In fact, the network operator has to pay 450$ more than optimal state due to security of lines and buses and to prevent damaging these sections.

Comparing result of this algorithm with proposed algorithm, it can be seen that the proposed algorithm is more efficient than above mentioned algorithm in finding optimal answer. Paying attention to these tables, it can be seen that using less from powerhouse 3 which is an expensive power plant and also through paying launching costs of powerhouse 2 just once, the proposed algorithm was able to supply the load and meet the needs of network security. This has caused total cost of the proposed algorithm to be less than the algorithm mentioned in ref [5].

4-2- Results Obtained for IEEE 30-Bus Network

In this network, ramp has not been considered for problem solution. Moreover, 10% of hour load in each hour has been considered as rotating store.

4-2-1- Problem Solution of Powerhouse for 30-Bus Network without Considering Security Constrains:

In this condition, according to the table 7 in this section, economic load dispatch is needed to be conducted in each repetition. To do so we have used Lagrange algorithm.

4-2-2- Problem Solution of Powerhouse for 30-Bus Network with Considering Security Constrains

In this subsection the underlying problem is solved for 30-bus network considering network security constrains. For this network, voltage of all buses are about 1.05 and 0.95 per unit. Table 8 shows optimal condition of powerhouse obtained using proposed algorithm [6]. According to the table, final cost for total network is 13204.24$, considering network security constrains and this amount was 13031.8$ without considering security constrains. This shows that about 200$ is needed to spend for network security in order to operate the network at confidant state. Paying more attention to these tables, it can be seen that powerhouses 4, 5 and 6 had higher costs at different points of working hours, and hence they are placed less in the circuit. Comparing this table with table 7, it can be seen that although powerhouses 5 and 6 are expensive, they are used more, considering network security provision.

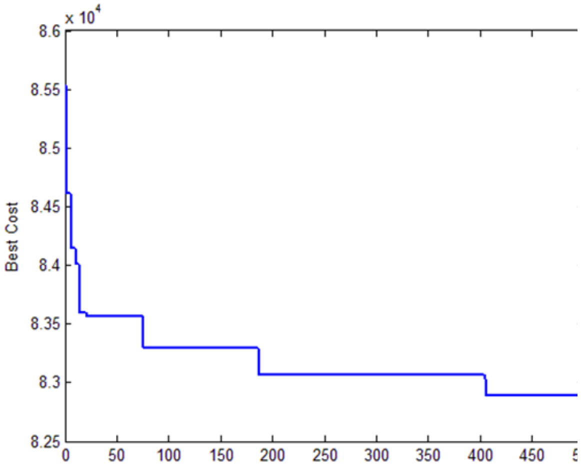

Fig.1. Improvement process for 6-bus UC

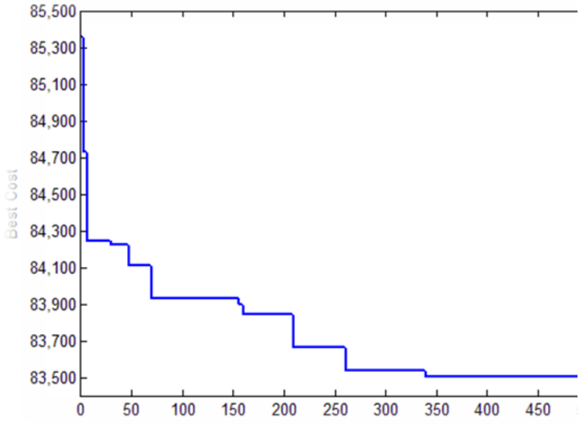

Fig.2. Improvement process for 6-bus SCUC

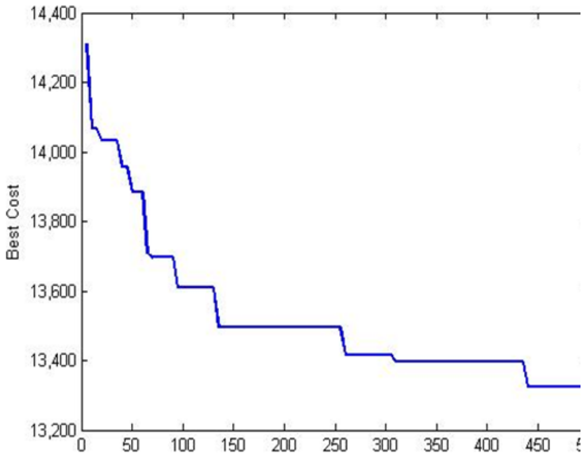

Fig.3. Improvement process for 30-bus UC

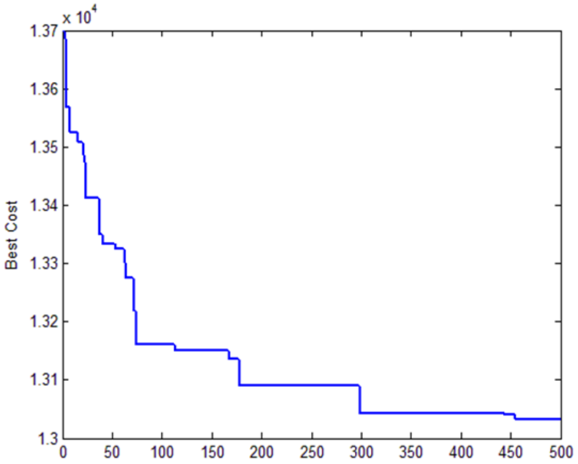

Fig.4. Improvement process for 30-bus SCUC

To show efficiency procedure of proposed algorithm in developed problem solution, improvement process in the results while using the algorithm have been shown in following figure. Results show that the algorithm can find optimal responses and can search for the answer [7].

5- Conclusion

Unit Commitment is one of the most important economic programs in power systems. In modern and traditional power systems, moreover economic aspect of the program, security is very important in the operation of the unit. So the operation of the unit faces the entry and participation of the units in consideration of networks' security constraints. The participation of units are defined as the level of optimization of the unit's production with determining the unit's on and off status and the level of unit's optimal production. In this study, Binary Particle Swarm Optimization is used for determining the best status of on and off state of powers' plants and for the optimal power flow algorithm is used. Security Constrained Unit Commitment is different from Unit Commitment. In this study two networks of 6-bus and 30-bus are studied in which the resulted data are reviewed with and without considering security constraints and also the results are compared with other achieved data.

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Appendix

Table.3. 6-bus uc with using the proposed algorithm

Unit	Total cost=82892.8 $ ،24 hours planning interval with proposed algorithm																							
G_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G_2	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
G_3	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0

Table.4. 6-bus uc with using reference [5]

Unit	Total cost= 83429.1 $ ،24 hours planning interval by reference 5																							
G_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G_2	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
G_3	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0

Table.5. 6-bus scuc with using proposed algorithm

Unit	Total cost= 83351.16 $،24 hours planning interval with proposed algorithm																							
G1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G2	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
G3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0

Table.6. 6-bus scuc by reference [5]

Unit	Total cost= 84267.89$ ، 24 hours planning interval by reference 5																						
G1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G2	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
G3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0

Table.7. 30-bus unit commitment

Unit	Total cost= 13031/8 $ ،24 hours planning interval the proposed algorithm																						
G1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G2	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G3	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G4	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0
G5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
G6	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0

Table.8. 30-bus security constrained unit commitment

Unit	Total cost= 13204.24، 24 hours planning interval using the proposed algorithm																						
G1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G2	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
G3	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	0	1	1	0
G4	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0
G5	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
G6	1	1	0	1	1	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1