A solution to Unit Commitment Problem using hGWO-PS Algorithm

Sushil Prashar[1], Vikram Kumar Kamboj[2,*], Kultaar Deep Singh[3]

[1]Ph.D Research Scholar, School of Electronics and Electrical Engineering, Lovely Professional University, India
[2]School of Electronics and Electrical Engineering, Lovely Professional University, Punjab, India
[3]Departmement of Electrical Engineering, Shaheed Bhagat Singh State Technical Campus, Ferozepur, India

ABSTRACT

Security Constrained Unit Commitment Problem (UCP) is the most appropriate timetable to turn-off or turn-on the power units to fulfil the electrical power need for a while and simultaneously keep the expense of power generation however much least as could be expected. UCP contains a large scale, nonlinear and mixed integer constrained optimization which to have a place with combinatory improvement issues. Demand of Electric Power is increasing day by day due to increase in Commercial, Residential and Agriculture load and it is very important to decide which generating unit should be kept on and how much power should be dispatched from the committed generating units so that time varying load demand can be meet. In the proposed research, the recently developed hybrid meta-heuristics search algorithm i.e. GWO-PS has been applied to solve the Unit Commitment problem of Electric power system. The efficiency of the proposed hybrid algorithm has been tested for standard IEEE Test system consisting of 4- and 10-generating units and it has been experimentally found that GWO-PS performs much better than GWO and PSO algorithm.

Keywords: Hybrid Search Algorithm, Meta-heuristics search, Unit Commitment Problem.

1. INTRODUCTION

Security Constrained Unit Commitment problem is a large scale, nonlinear and mixed integer constrained optimization which to have a place with combinatory improvement issues. The size of the Power system is growing exponentially due to heavy demand of electricity in all the sectors. Now a days, in power sector, there are different kinds of electric power generating stations like nuclear, thermal and hydro power plants etc. During a day, the demand of electric power is changing continuously and achieves various peak values. In this way, it is essential to choose which power generation units have to turn on and in which hour it is required in the power system framework arrange and furthermore, for what time period the generating unit should keep in shut down condition to main the cost viability of turning on and closing down of particular unit.

The whole procedure of making and computing on these choices is recognized as unit commitment (UC). The power generating unit that is planned for association with network of electrical power sector is known as the committed unit [1]. In power systems, the unit commitment problems refers such kind of problem which are associated with deciding the off/on conditions of producing units to limit the working expense for a specified time period. Power generators can't be directly turn on to fulfil up load demand of the electric power. So it is necessitated that the arranging of producing units is to be done in such a way, that there is sufficient amount of power generation accessible to satisfy the demand of the electrical load along with maintain malfunctions and failures under adverse conditions. Unit responsibility handle the power generation plan for electrical system for minimize fuel and operational costs while fulfilling system and constraints, for example, demand of electrical load and system save necessities over a set of time spans. UCP is fundamentally about discovery the most appropriate timetable to turn-off or turn-on the power units to fulfil the electrical power need for a while and simultaneously keep the expense of power generation however much least as could be expected. UCP contains a large scale, nonlinear and mixed integer constrained optimization which to have a place with combinatory improvement issues.

Here are numerous constraints included with UCP and consequently it is a tedious and complex process for computation and find out the optimum solution for UCP [2]. The UCP is to decide a small amount of price turn-off and turn-on arrangement for set of power generation units to fulfil an electricity need although fulfilling system physical and operational requirements connected with different power generation units. The price for start-up, shutdown, no load cost and fuel are included in the cost for production. The operational constraints which must be thought about include: the total amount of electric power generation should achieve the electricity demand along with losses to that generating system; there should be sufficient spinning reserve to withstand with any shortfall in electricity generations; the generation limit of each generator units must be within limit of its maximum and minimum capacity and minimum down time and minimum up time of each and every power generating unit should be pragmatic.

The unit commitment is intended to figure out with an appropriate generator commitment schedule for electric power sector over a time horizon of one day to a week. The fundamental objective of SCUCP is to minimize the total generation cost and satisfying some physical and system constrains forced on the system, for example, operating constraint, load-power generation balance, spinning reserve, minimum down time horizon and minimum up time horizon and initial status of such generating unit and so on [3]. A few ordinary techniques are accessible to take care of the UCP. The premier target of UCP is to locate the optimum scheduling for working of the accessible generating units to regulate the total cost of power generation and along with total cost for operation of that power generating unit. The complete cost of electric power generation incorporates with the cost of shut down of the unit, cost of fuel and the cost of start-up of the unit. The cost of fuel are reliant on price of the fuel the qualities information of power generating units, for example, heat pace of producing units, turn-on and off schedule and initial status of the power generation unit. So, the main objective of security constrained unit commitment problem is to minimize the total operating cost with satisfying those constrains [4], [5], [6].

2 PROBLEM FORMULATION

The generating power is distributed along with utilities of generator scheduling which will meet the time varying load demand for a specific time period is known as Unit Commitment Problem (UCP). The actual objectives of UCP is minimization of overall cost for production considering different system constraints. The overall cost of production including sum of shutdown cost & start-up cost, cost of fuel are given below:

$$\min(TC) = \sum_{h=1}^{H} \sum_{i=1}^{NG} \{F_{\cosh i}(P_{hi}) + SUC_{hi} + SDC_{hi}\} \quad (1)$$

The total cost of fuel over the scheduled time span ‘h’,

$$TC = \sum_{h=1}^{H} \sum_{i=1}^{NG} [F_{\cosh i} \times U_{hi} + SUC_{hi}(1 - U_{i,(h-1)}) \times U_{hi}] \quad (2a)$$

$$TC = \sum_{h=1}^{H} \sum_{i=1}^{NG} [(A_i P_i^2 + B_i P_i + C_i) \times U_{i,h} + SUC_{i,h}(1 - U_{i,(h-1)}) \times U_{i,h}] \quad (2b)$$

Here, cost for fuel $F_{\cos ih}(P_{ih})$ is stated as quadratic design that mostly working by researchers, also named as equation of convex function.

For the cost of fuel of (n) unit at (t) hour can be mathematically represented as such an equation which is given below:

$$F_{\cos ih}(P_i) = A_i P_i^2 + B_i P_i + C_i \quad (3)$$

Where A_i B_i and C_i are represented as coefficients of cost that may expressed as $\$/h$, $\$/MWh$ and $\$/MWh^2$ correspondingly.

Start-up cost can mathematically represented by step function which is given below:

$$STC_{ih} == \begin{cases} HSU_i; & for \quad T_i^{DW} \le T_i^{UP} \le (T_i^{DW} + T_i^{COLD}) \\ CSU_i; & for \quad T_i^{UP} > (T_i^{DW} + T_i^{COLD}) \end{cases} \quad (4)$$

In usual value of the Shutdown cost for standard system is denoted as zero and this can be established as fixed cost followed by the eqn. (5).

$$SDC_{ih} = KP_{ih} \quad (5)$$

Where K is represented as incremental cost for shut-down.

Which is subjected through some constraints followed by: (1) System constraints and (2) Unit constraints

System Constraints:

System constrains are interrelated with all generating unit existing in the systems. The systems constrains are characterised into two types like:

Power Balance or Load Balance Constraints

In power system the constraint including power balance or load balance is more important parameter consist of summation of whole committed generating unit at t[th] time span must be larger than or equivalent to the power demand for the particular time span 't'

$$\sum_{i=1}^{NU} P_{i,h} \times U_{i,h} = PD_i \tag{6}$$

Spinning Reserve (SR) Constraints

Reliability of the system can be considered as facility of extra capability of power generation that is more important to deed instantly when failure is occurred due to sudden change in load demand for such power generating unit which is already running. The extra capability of power generation is recognized as Spinning Reserve which is exactly represented as:

$$\sum_{i=1}^{NU} P_{i,h}^{MAX} \times U_{i,h} \geq PD_h + SR_h \tag{7}$$

Step1: Sort the generators in descending order of maximum generating capacity.
Step2: *for* g = 1 to G
$\quad$ *if* $u_{g,h} = 0$
$\quad\quad$ then $u_{g,h} = 1$
$\quad\quad$ *else if* $T_{g,h}^{OFF} > MDT_g$
$\quad\quad$ then $T_{g,h}^{ON} = T_{g,h-1}^{ON} + 1$
$\quad\quad$ and $T_{g,h}^{OFF} = 0$
Step-3: Verify new generating power of units.
Step-4: if $\sum_{j=1}^{NG} P_{j,max} u_{j,h} \geq D_h + R_h$ then stop the algorithm, else go to step-2.
Step-5: if $T_{OFF}^{g,h} < MDT_g$ then do $l = h - T_{g,h}^{OFF} + 1$ and set $u_{g,h} = 1$
Step-6: Calculate $T_g^l = T_{g,l-1}^{ON} + 1$ and $T_{g,l}^{OFF} = 0$
Step-7: if l>h, Verify generator output power for $\sum_{j=1}^{N} P_{j,max} u_{j,h} \geq PD_i + SR_i$, else increment l by 1 and go to step-5

Fig. 1(a). PSEUDO code of SR repairing

Constraints for Power Generating Unit: The specific constraints related with particular power generating unit exist in the systems are called generating unit constraint.

Thermal unit constraints: Thermal power units are controlled manually. This types of unit need to undertake the change of temperature gradually. So it take certain time span to take the generating unit accessible. So some crew members are essential to execute the maintenance and procedure of some thermal power generating units.

Minimum up Time: This constraint is defined as here will be minimum period of time previously the unit can be start over when the unit have already been shut down which is mathematically defined as:

$$T_{i,h}^{ON} \geq T_i^{UP} \tag{8}$$

Where, $T_{i,h}^{ON}$ is defined as interval through which the generating unit i is constantly ON (in hours) and T_i^{UP} is defined as minimum up time (in hours) for the generating unit n.

Minimum down Time: When the power generating units will be DE-committed, there is required least period of time for recommitted of the unit which is mathematically given as:

$$T_{i,h}^{OFF} \geq T_i^{DW} \tag{9}$$

Where, $T_{i,h}^{OFF}$ is time period for which generating unit n is constantly OFF (in hrs) and T_i^{DW} is denoted as minimum down time (in hours) for the unit.

To adequate minimum downtime and up time repair by heuristic mechanism is accepted those stages are stated as below in Fig. 1(b).

for h=1 to H

  if h==1

    Compute $T_h^{ON} = T_{h_0}^{ON} U_{hi} + U_{hi}'$

    Compute $T_h^{OFF} = (T_{h_0}^{OFF})' \bar{T}_h^{ON} + \bar{T}_h^{ON}$

    else

      Compute $T_h^{ON} = T_{h-1}^{ON} U_{hi}' + U_{hi}'$

      Compute $T_h^{OFF} = T_{h-1}^{OFF} \bar{T}_h^{ON} + \bar{T}_h^{ON}$

  end

end

Fig. 1(b). PSEUDO code for MUD/MUT constraints

Max and Min Electric Power Generating Limits: All electricity generating unit have its individual max/ min electric power generating limit, below and outside which will cannot produce and this is known as maximum and minimum power limits, which is mathematically written as:

$$P_i^{MIN} \leq P_{i,h} \leq P_i^{MAX} \quad (10)$$

Initial Status for operation of electrical units: For every units have initial operating position that must proceeds as the day's earlier generation scheduled are taken into consideration, thus each and all generating units can fulfils its lowest down/up time.

Unit Accessibility Constraint: For the constraint shows accessibility of power generating unit surrounded by any of the resulting various circumstances:

- Accessible or Non Accessible
- Must Outage or Out
- Must running condition

Initial Status of Electricity Generation Unit: It signifies value of initial grade of power generating unit. Its favourable rate signifies the position of current generating unit which already in up condition, which mean about numeral time periods of the generating units are previously up, and for its negative value which is an index of the integer of hour then power generating unit has been previously in down condition. For the position of generating unit +/- earlier the 1st hour through the schedule which is an essential feature to define where its newest situation interrupts the constraint of T_i^{UP} & T_i^{DW} . LOLH is properly taken into consideration while solving SCUC Problem.

Crew Constraint: When any power plant consist of added one units and they couldn't turn on at the same time period. So here need more than one crew members to attend such units in a same time while starting up.

3 HYBRID GWO-PS ALGORITHM

In the proposed research, the recently developed grey wolf optimizer [7] has been hybridized with Pattern Search algorithm to improve the exploitation phase of the existing GWO algorithm. The mathematical formulation for the hybrid GWO-PS algorithm can be found in [8] and PSEUDO code for the proposed optimizer has been shown in Fig.2.

Initialize the grey wolf population X_i, where $i \in 1, 2, 3, \ldots, N$
Initialize $a, \vec{A}$ and $\vec{C}$
Calculate the fitness of each search agents using objective function
Assign $X_\alpha \leftarrow$ The best search agents
$X_\beta \leftarrow$ The second best search agents
$X_\delta \leftarrow$ The third best search agents
Update the position of X_i using the Pattern Search method
while $(iter < Iter_{max})$
    for each search agents
        Update the position of the current search agent
    endfor
    Update $a, \vec{A}$ and $\vec{C}$
    Update X_{α}, X_{β} and X_δ
    $iter = iter + 1$
end while

Fig. 2: PSEUDO code for proposed GWO-PS algorithm

4 RESULTS & DISCUSSIONS

The recently developed GWO-PS algorithm has been applied to solve security constrained unit commitment problem of electric power system. In order to validate the results using GWO-PS algorithm, A standard IEEE Test system with 4- and 10-generating units system has been taken into consideration [9] and Generation Schedule of Committed Units for 4-units system has been shown in Table-1 and committed status of 10-units system is shown in Fig.3 and its corresponding dispatch schedule is shown in Fig.4. The 40 search agents are taken into consideration for effective research study.

Table-1.: Test Results for 4-generating unit system

Hour	Commitment Status				Generation Schedule			
	U1	U2	U3	U4	U1	U2	U3	U4
1	1	1	0	0	300	150	0	0
2	1	1	1	0	300	205	25	0
3	1	1	1	1	300	250	30	20
4	1	1	1	0	300	215	25	0
5	1	0	1	1	300	0	80	20
6	1	0	1	0	255	0	25	0
7	1	0	1	0	265	0	25	0
8	1	1	0	0	300	200	0	0
					Total Cost($)		74476.00	
					Time(Sec.)		20.863569	

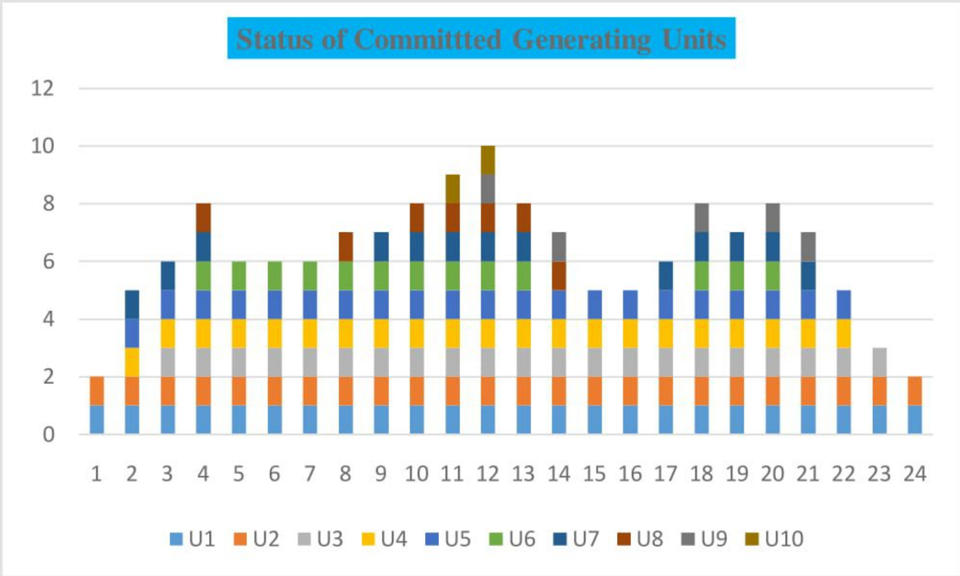

Fig-3.: Committed Units for 10-Unit system at SR=10%

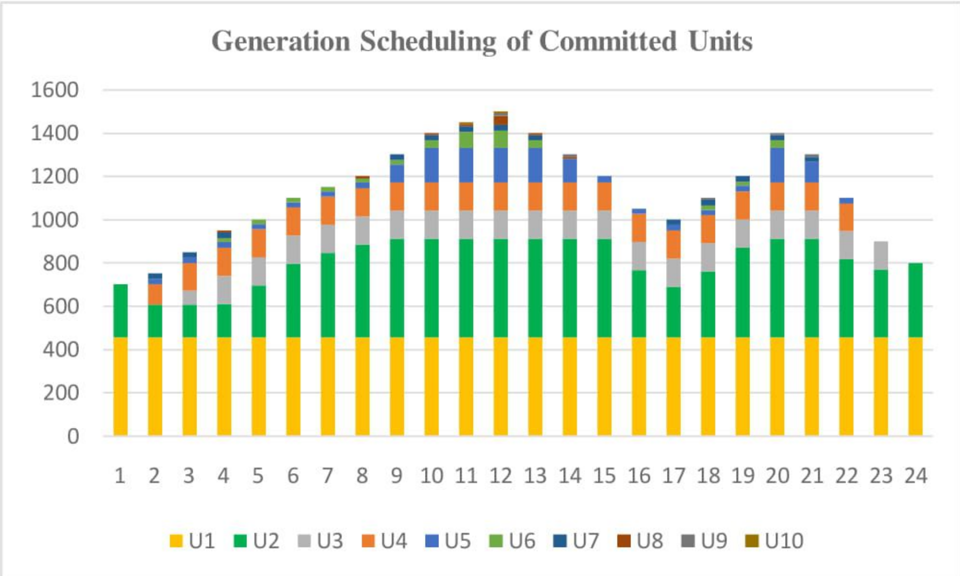

Fig. 4.: Hourly dispatch of Committed Units for 10-Unit system at SR=10%

CONCLUSIONS

The proposed GWO-PS has been successful applied to the Unit Commitment Problem and its effectiveness has been verified for standard IEEE test systems consisting of 4- and 10-generating units and experimentally it has been found that the commitment results of GWO-PS are better than PSO and classical GWO algorithm and similar kind of algorithm can be applied to solve Security constraints units commitment problem and profit based unit commitment problem as a future research.

REFERENCES

[1]. V. Kumar, S. K. Bath, and J. S. Dhillon, "Electrical Power and Energy Systems Implementation of hybrid harmony search / random search algorithm for single area unit commitment problem," Int. J. Electr. POWER ENERGY Syst., vol. 77, pp. 228–249, 2016.

[2]. M. Reza Norouzi, A. Ahmadi, A. Esmaeel Nezhad, and A. Ghaedi, "Mixed integer programming of multi-objective security-constrained hydro/thermal unit commitment," Renew. Sustain. Energy Rev., vol. 29, pp. 911–923, 2014.

[3]. E. Nasrolahpour and H. Ghasemi, "A stochastic security constrained unit commitment model for reconfigurable networks with high wind power penetration," Electr. Power Syst. Res., 2014.

[4]. V. K. Kamboj, S. K. Bath, and J. S. Dhillon, "Solution of non-convex economic load dispatch problem using Grey Wolf Optimizer," Neural Comput. Appl., 1934.

[5]. V. K. Kamboj, S. K. Bath, and J. S. Dhillon, “Multiobjective multiarea unit commitment using hybrid differential evolution algorithm considering import/export and tie-line constraints,” Neural Comput. Appl., vol. 28, no. 11, pp. 3521–3536, 2017.
[6]. V. K. Kamboj, S. K. Bath, and J. S. Dhillon, “A novel hybrid DE–random search approach for unit commitment problem,” Neural Comput. Appl.
[7]. S. Mirjalili, S. M. Mirjalili, and A. Lewis, “Grey Wolf Optimizer,” Adv Eng Softw, vol. 69, p. 46, 2014.
[8]. V. K. Kamboj, A. Bhadoria, and N. Gupta, “A Novel Hybrid GWO-PS Algorithm for Standard Benchmark Optimization Problems,” Ina. Lett., vol. 3, no. 4, pp. 217–241, 2018.
[9]. V. K. Kamboj, “A novel hybrid PSO – GWO approach for unit commitment problem,” Neural Comput. Appl., 2015.