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Commitment of hydro thermal generation scheduling of a large power system with cooling –banking constraint using Gravitational Search Algorithm

KEYWORDS: Short term hydro thermal scheduling, Gravitational Search Algorithm, Unit Commitment, Cooling- Banking constraint

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ABSTRACT *This paper presents a new optimization algorithm i.e gravitational search algorithm (GSA) based on the law of gravity and mass interactions for solving the Unit Commitment problem in hydro thermal large power system with cooling –banking constraint for a duration of one day having 24intervals such that total operating cost can be minimized satisfying both the load balance constraint and other operating constraints of hydro and thermal systems. Numerical results for a test case show that GSA algorithm is capable of finding very nearly global solutions and achieves cheaper generation schedule in comparison to the results of the other heuristic optimization techniques reported in literature.*

I. Nomenclature

$P_{si(t)}$: Power generation of thermal unit i in hour t

$P_{hj(t)}$ Power generating or hydro plant j in hour t

$F_{i(t)Psi(t)}$: Production cost for $P_{si(t)}$

T : Number of scheduling hours

N_h : Number of hydro units

N_s : Number of thermal units

$P_{d(t)}$: System load demand in hour t

$P_{loss(t)}$: System transmission network losses in hour t

$V_{j(t)}$: Water volume of the reservoir of hydro unit j at the ending of hour t

$I_{j(t)}$: Natural inflow into reservoir j in hour t

$Q_{j(t)}$: Water discharge of hydro unit j in hour t

S_{jt} : Water spillage of P/S plant j in hour t

P_{SiMAX} Maximum generation limit of Thermal unit i

P_{SiMINi} -Minimum generation limit of Thermal unit i

P_{hjMAX} -Maximum generation limit of hydro unit j

P_{hjMIN} -Minimum generation limit of hydro unit j

a_i, b_i, c_i Thermal generation cost coefficients of unit i

$C_{j,1,}C_{j,2},C_{j,3},C_{j,4,}C_{j,5},C_{j,6}$ Hydro power generation coefficients of hydro unit j

V, j^{begin} -Initial storage volume of j reservoir in m^3

V, j^{end} -Final storage volume of reservoir j in m^3

II. Introduction

The main objective of the Short term hydro thermal scheduling is to minimize the total system operating cost represented by the fuel cost required for the system thermal generation over the optimization interval of one day to one week. The load demand of a power system is not constant for all the scheduling intervals, however may exhibit large differences from minimum and maximum demand. , hence it is not economical to run all available units all the time, and it is necessary to decide in advance which generators are to startup, when to connect them to network, the sequence in which the operating units should be shutdown and for how long is the task of unit commitment. The solution to this problem, if the time span is a day gives a plan for the optimal quantity of water to be discharged from hydro plant and the corresponding thermal generation such that the total fuel cost of the thermal plants over the day is minimized subject to the operating constraints of the hydro and thermal plants and the load balance constraint.

Conventional methods based on Lagrangian multiplier and gradient search techniques [1] require models of hydro as well as thermal plants to be represented as piecewise linear or polynomial approximations of monotonically increasing nature. But such an approximation may lead to suboptimal solution resulting in huge loss of revenue over the time. Methods based on Dynamic Programming [2],[3], Lagrangian Relaxation [4] to solve the short-term unit commitment problems was found that it provides faster solution but it will fail to obtaining solution feasibility and become more complex. Stochastic search algorithms like simulated annealing [5], Genetic Algorithm [6], Evolutionary Programming[7-8],with cooling banking constraint [14], Particle Swarm Optimization [9-10] have been proved to be very exciting in solving complex power systems problems, but these heuristic methods do not always guarantee the globally optimal solution. In this paper a new population based search algorithm called Gravitational search algorithm [11-12] is applied to a test system which has been adopted from [14] and the simulation results are compared to that of Dynamic Programming, EP etc [14].

III. Problem Statement

The problem statement includes the quadratic cost characteristics, startup cost of thermal power system and operating constraints of hydro and thermal generating u s. As hydrogenating units do not incur any fuel cost, the HS problem is aimed to minimize the total thermal cost while making use of the availability of hydro resource as much as possible.

A. Objective function and constraints

The objective function and associated constraints of the problem are formulated as follows. The objective is to minimize the production costs of thermal units while satisfying various constraints. With discretization of the total schedul-

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ing time into a set of shorter time intervals (say, one hour as one time interval), the scheduling of HT units can be mathematically formulated as a constrained nonlinear optimization problem as follows:

Minimize $\sum_{t=1}^{T}\sum_{i=1}^{N_s} F_i^t\left(P_{si}^t\right)$ (1)

Subject to the following constraints:

(i) System Power Balance constraint-

$$\sum_{i=1}^{N_s} P_{si}^t + \sum_{j=1}^{N_h} P_{hj}^t - P_d^t - P_L^t = 0 \quad (2)$$

The real power generated by the Thermal unit and the Hydro unit must meet the load demand and the system transmission loss.

(ii) Spinning Reserve Constraint-Spinning reserve is the total amount of generation available from all units synchronized on the system minus the present load plus the losses in the system. It is necessary to prevent drop in system frequency.

$$1 \le t \le T, \sum_{i=1}^{N} P_{MAX,i} U_t \ge (P_{D,t} + R_t) \quad (3)$$

$U_{i,t}$ is the Status of unit I at time t., R_t is the spinning reserve at time t.

(iii)Thermal Constraints-A thermal unit undergoes gradual temperature changes and this increases the time period required to bring the unit online. This time restriction imposes various constraints on generating unit. Some of the constraints are minimum up/down time constraints and crew constraints.

If the units are already running, there will be minimum time before which the units cannot be turned OFF and the constraint is given by equation $T_{on,i} \ge T_{up,i}$

(4)

If the units are already OFF, there will be a minimum time before which they cannot be turned ON and the constraint is given by equation

$$T_{off,i} \ge T_{down,i} \quad (5)$$

(iv) Must run units-Some units in the power system are given must run status in order to provide voltage support for the network.The Hydro Generation P_h is assumed to be a function of effective head and the rate of water discharged through the turbines

$$P_h = f(h,q) \quad (6)$$

(v)Thermal Plant generation limit-

$$P_s(\min) \le P_s(t) \le P_s(\max) \quad (7)$$

(vi) Hydro Plant generation limit-

$$P_h(\min) \le P_h(t) \le P_h(\max) \quad (8)$$

(vii) Water Dynamic. Balance-

$$V_j^t = V_j^{t-1} + I_j^t - Q_j^t - S_j^t \quad (9)$$

(viii) Water Discharge limits-

$$Q_j(\min) \le Q_j(t) \le Q_j(\max) \quad (10)$$

(ix) Reservoir limits -

$$V_j(\min) \le V_j(t) \le V_j(\max) \quad (11)$$

The initial volume and final volume that is to be retained at the end of the scheduling period

$$V_j^{t=0} = V_j^{begin} \quad (12)$$

$$V_j^{t=T} = V_j^{end} \quad (13)$$

(x) Hydro plant unit power generation characteristics
The hydro power generated is related to the reservoir characteristics as well as water discharge rates. Hydro power output is a function of the volume of the reservoir and discharge rate. The equation representing the hydro power generation characteristics is given in equation (14)

$$P_h(j,t) = C_{j,1}V(j,t)^2 + C_{j,2}Q_h(j,t)^2 + C_{j,3}[V_h(j,t)Q_h(j,t)]C_{j,4}V_h(j,t) + C_{j,5}Q_h(j,t) + C_{j,6} \quad (14)$$

IV. gravitational search algorithm based approach of solving hydro thermal scheduling with unit commitment and cooling –banking constraint

A) Gravitational Search Algorithm: Introduction- GSA is one of the recent additions to heuristic algorithms was developed by Rashedi et al. in 2009 [11] .GSA is followed by the physical law of gravity and the law of motion. In the proposed algorithm, agents are considered as objects and their performance is measured by their masses. All these objects attract each other by the gravity force and this force causes a global movement of all objects towards the objects with heavier masses.

B) GSA based approach to hydro thermal UCP-The steps followed are given below

Step 1. Search space identification- In this system hydro discharges are randomly generated between their limits with N_p as no of population and the number of scheduling intervals as Z and number of hydro units as N_h.

Step 2. Generate initial population between minimum and maximum value. To satisfy the constraints on the initial and the final reservoir storage states, a dependent hydro discharge rate qd is randomly selected

Step 3.Fitness evaluation of agent.

Step 4 Update Gravitational constant $G(t)$, $G(t) = G_0 e^{-\alpha \times iteration/\max imumiteration}$, $best(t)$, $best(t) = \min_{j\varepsilon\{1,\dots m\}} fit_j(t)$, $worst(t)$, $worst(t) = \max_{j\varepsilon\{1,\dots m\}} fit_j(t)$ and, $M_i(t)$, $i = 1,2,\dots m$, m no of agents. $M_i(t) = m_i(t)/\sum_{j=1}^{m} m_j(t)$, $m_i(t) = fit_i(t) - worst(t)/best(t) - worst(t)$

Step 5. Calculation of total force in different direction, [11]

Step 6. Calculation of acceleration and velocity, [11]

Step 7.Updating agents position

Step 8. Repeat Step 3 to Step 7 until the stop criteria is satisfied

Step 9. Stop

V. CASE STUDY
A Power system consisting of four hydro generating units and seven thermal generating units have been considered as the case study. A time period of 24 intervals each of one hour, representing 24hour of a day is considered and the unit commitment problem is solved for seven thermal units of a power system. The total hourly load demand of hybrid system, the cost function parameters of each unit for thermal system, volume and discharge limits for hydro system, and hydro coefficients for hydro system are adopted from reference [14]. The convergence characteristic of the proposed GSA method is depicted in Fig1. The hourly hydro and thermal power generations and total generation for the entire scheduling period are provided in Fig. 2 . Table 1 provides the comparative analysis of the cost of power generation of different methods. One can see the applicability and viability of proposed GSA method over others.

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The Optimization result of GSA on the test system are given below .

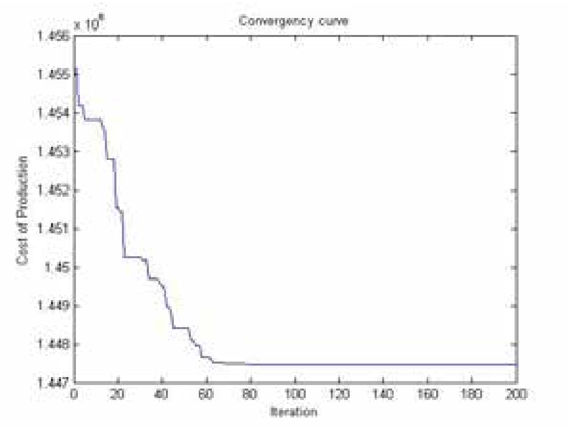

Fig. 1 Convergence Characteristics of the GSA on the test system

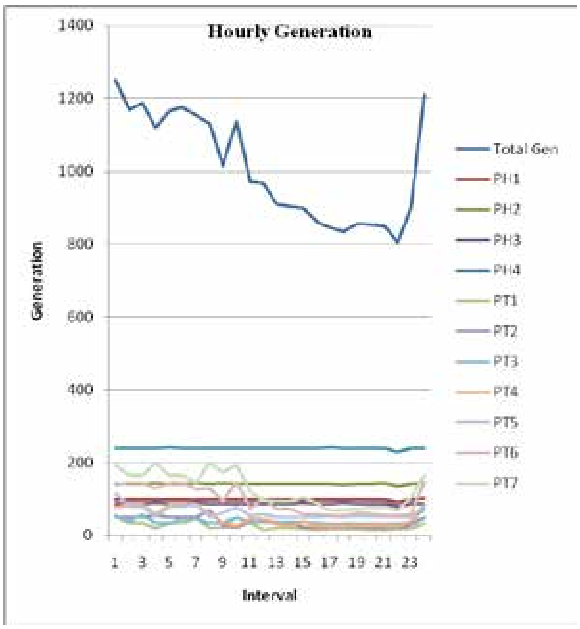

Fig. 2 Hourly hydro, Thermal and total generation on the test system

Table-1 Comparison of total Production cost

Method	Total Production cost
Dynamic Programming	Rs24,03,000.00
Evolutionary Programming	Rs16,33,990.00
Evolutionary Programming with Cooling Banking	Rs16,11,560.00
Gravitational Search Algorithm with Cooling Banking	Rs14,47,469.00

VI. Conclusion

A new algorithm called Gravitational Search Algorithm was developed and demonstrated to solve commitment of hydro thermal scheduling of a large power system with cooling banking constraint. Results show that GSA based algorithms are more capable of finding highly near-global solutions than Dynamic Programming, Evolutionary Programming etc. The optimal cost obtained by the GSA is quite cheaper than the other published work for the system adopted. In future, attempts can be made to apply the hybrid gravitational search algorithm to large hydro thermal system in conjunction with wind energy by incorporating emission, spinning reserve and reliability constraints.

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