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UNIT COMMITMENT USING HARMONY SEARCH ALGORITHM WITH VARYING INITIAL STATUS

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ABSTRACT

In power system, unit commitment is pivotal in improving the scheduling of the thermal units which results in the reduction in cost value. Unit commitment is the amalgamation of evaluating the operational units as well as predicting the generation of each unit by maintaining the system constraints. In this paper, the conventional unit commitment was solved using the harmony search algorithm with varying on-off initial time. The potential of the proposed method is tested on four generating unit system and made a comparison with existing methods. The variation of initial time values makes a better global value and the convergence of the system is quicker with the elimination of local optima.

Keywords: unit commitment, scheduling, harmony search, optimization, economic dispatch.

1. INTRODUCTION

In many countries, the configuration of the power sector is very important and essential to electrical engineers. Power system meets many tasks like security, growing demand, sustainability of fuel sources, reduction of fuel price, etc. Over a decay, the demand factor is enhancing with the rapid residential and industrialization. Due to the unavailability of storage of electrical energy right operation is essential in the real power generation of thermal units. Pivotal optimization is required for the scheduling of thermal units. Unit commitment is one of the optimization problems in predicting the effective utilization of fossil energy in electrical plants.

Unit commitment predicts the on/off status of generating units, and based on this economic operation is integrated by satisfying both inequality and equality constraints. Load attains a peak value, low values on a load curve during a day, this requires essential turning on and turning off generating units i.e., what time it needs to be connected or disconnected in the power network represents the unit commitment. Unit commitment is a mixed integer linear program, nonlinear and large-scale problem. The precise solution for the unit commitment optimization problem can be evaluated with the iteration of all possicombinationstion of thermal generating units which is tedious in realiapplicationsation. To compensate for this problem, sophisticated methods were introduced for predicting the scheduling of thermal units for real-sized power system networks. The cost characteristic is represented in quadratic form which is in convex nature. Unit commitment optimization problem is formulated for the minimization of cost value subjected to many constraints. The related constraints are minimum downtime, minimum uptime, ramp constraints, crew constraints, unit capability limit constraint [1] and reserve constraints, prohibited operating zone, and ramp rate limits, which leads to non-convexity. Many techniques were implemented to solve the unit commitment optimization problem concerning with conventional, heuristic, and meta-heuristic.

Conventional methods like lambda iteration and the newton method are used to solve the problems. With the incorporation of constraints, the non-convex problem cannot be handled by conventional methods. This issue can be overcome by the Lagrangian relaxation (LR) approach [2], dynamic programming (DP) [3], priority list (PL) [4], integer/mixed integer programming (MIP) [5], branch bund method (BBM) [6]. The drawback associated with LR method is, it is inherent for sub-optimality. The disadvantage associated with DP is what limits the startup cost related to the time-dependent and suboptimal treatment of minimum uptime and downtime. PL method is very fast and generates schedules concerned with the high operating cost. MIP neglects the infeasible subsets as well as the reduction in search space while solving unit commitment problems. In BBM the convergence occurs only when single decision variables are avail in the subset. To overcome the above drawback, stochastic search methods, where implemented like genetic algorithm (GA) [7], Evolutionary programming (EP) [8], artificial bee colony [9], particle swarm optimization (PSO) [10], and simulated annealing (SA) [11]. These methods solve nonlinear characteristics of the cost function with better convergence and the best global solution. But the drawback associated with the stochastic methods is that it suffers from the enhancement of dimensionality. In this paper, a New Harmony search algorithm is applied with varying initial on/off time to solve optimization problem concern to unit commitment. The objective of the proposed work is to minimize the cost values. Initial stage the on/off status of the committed units is evaluated and later followed by the economic dispatch for sharing of load demand.

2. PROBLEM FORMULATION

The total generation cost of a thermal unit is the amalgamation of fuel cost as well as startup cost. The objective function of cost minimization is represented as follows:

$$min \sum_{o=1}^{M} \sum_{t=1}^{T} F_o\big(P_o(t)\big)U_o(t) + SUC_o\big(1 - U_o(t-1)\big)U_o(t) \qquad 2.1$$

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where F_o is the cost function, $P_o(t)$ is the real power generation of o[th] thermal unit at time 't'. SUC_o is the start-up cost of o[th] thermal unit. $U_o(t)$ is the on/off status of o[th] thermal unit at time 't' hour. T is the total period of scheduling with time horizon of one hour and T is considered for 8 time intervals. M is the total number of thermal units for real power generation. The cost function is indicated in quadratic form which is presented as

$$F_o\big(P_o(t)\big) = a_o + b_oP_o(t) + c_oP_o^2(t) \qquad 2.2$$

Where a_o, b_o, c_o are the cost coefficients, each generator is subjected to constraints of inequality and equality. Thermal units are associated with two ways of starting namely hot start up and cold start up.

$$SUC = \begin{cases} HC(t), & if\ T_{o,down} \leq T_{o,off} \leq H_{o,off} \\ CSC(t), & if\ T_{o.off} > H_{o,off} \end{cases} \qquad 2.3$$

$$H_{o,off} = T_{o,down} + T_{o,cold} \qquad 2.4$$

where SUC is the start-up cost and its values is varying one, $HC$is the hot start-up cost, CSC is the cold start-up cost. $MD_{o,down}$is the minimum downtime of o[th] thermal unit. $T_{o,cold}$ is the cold start time of thermal unit o. $TC_{o,off}$ is the continuous off time of unit o. All the thermal units are subjected to equality and inequality constraints.

2.1 Constraints

The constraints that are subjected to the thermal units are as follows:

a. Power limit constraint

The generation of each thermal unit is maintain within the prescribed limits. Maximum power generation limit and minimum power generation limit are associated for each thermal unit. The generation of real power should be maintained within this limit and the corresponding inequality constraint is represented as

$$P_o^{min} \leq P_o \leq P_o^{max} \qquad 2.5$$

whereP_o^{min}, P_o^{max} are the minimum and maximum power generation limits of thermal unit 'o' respectively.

b. Power balance constraint

The total thermal generation of all units should meet the load demand. As the load is varying the sum of power generation of all thermal units must be varied in order to meet the load demand. This constraint is termed as equality constraint.

$$\sum_{o=1}^{M} P_o(t) * U_o(t) = D(t) \qquad 2.6$$

D(t) indicates the load demand for time 't'.$U_o(t)$is the on/off status of unit 'o' at time 't'.

c. Minimum downtime and uptime

Each thermal unit is associated with minimum time interval from state of started up to shut down and vise-versa i.e. shut-down state to started-up state. The corresponding mathematical equations are represented as:

$$T_{o,on} \geq T_{o,up}$$
$$T_{o,off} \geq T_{o,down} \qquad 2.7$$

where $T_{o,on}$ is 'o' unit continuous uptime and $T_{o,up}$ is the minimum uptime of unit 'o' and $T_{o,off}$ is the continuous off time of unit 'o', minimum time down is indicated as $T_{o,down}$ for unit 'o'.

d. Spinning reserve

Redundancy of power is essential to ensure safe work in the power system due to any accident. Maintenance of spinning reserve is ten percent of total demand.

$$\sum_{o=1}\sum_{o=1}^{M} P_o(t).U_o(t) \geq D(t) + SR(t) \qquad 2.8$$

where SR(t) is the spinning reserve at time 't'.

3. METHODOLOGY

3.1 Harmony Search Algorithm

This algorithm is developed based on the music improvisation strategy by adjusting the pitches of an instrument to achieve better harmony [12]. Harmony memory is initialized in the harmony search which stores the vectors that belong to search space. Harmony memory size predicts the respective vectors to be put aside. The following steps are adopted for harmony search algorithm.

a) Before the commencement of iterative process optimization problem is defined and all the initial parameters are to initialize such as Harmony memory considering rate (HMCR), Harmony memory size (HMS), Pitch adjustment rate (PAR), Harmony memory (MH).
Optimization problem is defined as
Minimize CF(y)

Subjected y_i Є Y_ii=1,2,3……..M 2.9

where CF(y) is the cost objective function, $Y_i$is the set of values of possible range of individual decision variables i.e. Y_i={y_i(1),y_i(2),y_i (3)………y_i(k)}. Yi is maintained within the range of limits, upper limit and lower limit. Y_i^{max}, Y_i^{min}
$Y_i^{min} \leq$ Yi$\leq Y_i^{max}$,

Where M is the number of decision variables, k is discrete variables. Both PAR and HMCR are used to improve vector solution.

b) Harmony memory is initialized with a vector solution of randomly generated and sorted based on the objective function values.

c) Based on the pitch adjustment, memory considerations, and randomization a New Harmony vector is produced from the existing harmony memory. The feasibility of producing new vector depends on HMCR parameter whose value varies between 1 and 0.

$$y_i' = \begin{cases} y_i' \in \{y_i'^1, y_i'^2, \ldots . y_i^{HMS}\} & \text{with probability HMCR} \\ y_i' \in Y_i & \text{with probability } (1 - \text{HMCR}) \end{cases} \quad 2.10$$

Values from the HM is selected based on the probability setting rate of HMCR and (1-HMCR) probability setting rate of choosing values from the entire feasible range.

d) After the generation of New Harmony vector $y_i = (y_1', y_2', \ldots . . y_N')$ it should be tested for pitch adjustment. In this process, pitch adjustment rate sets the adjustment rate for the pitch which was taken from the harmony search.

Pitch adjustment $y_i' =$

$$\begin{cases} yes & with\,probability\;\; PAR \\ No & with\,probability\;(1 - PAR) \end{cases} \quad 2.11$$

If the decision of the pitch adjustment is 'yes' which indicates a modification of vector.

$$y_i' = y_i(k + m)$$
$$y_i' = y_i' + \alpha \quad 2.12$$

'm' is concern to neighboring index m whose range is { . . . -2,-1,1,2….} and $bw * u(-1,1)$ is the value of α, bw is the arbitrary distance bandwidth.

e) Harmony memory is updated with New Harmony vector having a better fitness values compared with less fitness harmony vector and then the fitness values are sorted in harmony memory.

f) If the convergence criteria is reached the computation is terminated or else repeat step 3 to step 5.

Table-1. Data related to four generator system.

P_{max} (MW)	P_{min} (MW)	a_i	b_i	c_i	Hot start cost($)	Cold start cost($)	Min up(h)	Min down(h)	Cold start time(h)	Initial status(h)
300	75	684.74	16.83	0.0021	500	1100	5	4	5	8
250	60	585.62	16.95	0.0042	170	400	5	3	5	8
80	25	213	20.74	0.0018	150	350	4	2	4	-5
60	20	252	23.6	0.0034	0	0.02	1	1	0	-6

Table-2. Demand of four generator system on hour basis.

Hours	1	2	3	4	5	6	7	8
Demand (MW)	450	530	600	540	400	280	290	500

4. SIMULATIONS

Harmony search algorithm is applied to four unit system and its cost coefficient, maximum and minimum generation limits, initial values, hot start-up cost, cold start-up cost, minimum uptime and down time values are shown in Table-1 [16]. The four unit system is subjected to load demand with time horizon of one hour for eight hours of load shown in Table-2 [16]. The initial parameters values are considered before the commencement of iterative process. Careful selection of parameters is essential for profitable results in the objective function.

The parameters assigned value is harmony memory considering rate, harmony memory size, Pitch adjustment rate 0.95, 100, and 0.3. The commitment of thermal units for eight hours of different load demand with time horizon of one hour is shown in Table-3. First and second generators are committed for all load demand whereas third generator committed for first three loads i.e. 450MW, 530MW, and 600MW, fourth generator is committed for no load demand which can be illustrated in Table-3. Dispatching of load demand among the four thermal unit as well as cost of individual load demand can be observed in Table-4. The total cost of the four unit thermal system is 74,089.544 ($).

Table-3. Unit commitment of four unit system.

Hour	G_1	G_2	G_3	G_4
1	1	1	1	0
2	1	1	1	0
3	1	1	1	0
4	1	1	0	0
5	1	1	0	0
6	1	1	0	0
7	1	1	0	0
8	1	1	0	0

Table-4. Load sharing of generating unit using harmony search algorithm.

Hour (h)	G_1 (MW)	G_2 (MW)	G_3 (MW)	G_4 (MW)	Cost ($)
1	292.8571	132.1429	25	0	9,425.038
2	300	205	25	0	10,892.240
3	300	250	50	0	12,262.860
4	300	240	0	0	10,818.280
5	276.1905	123.8095	0	0	8,241.788
6	196.1905	83.80952	0	0	6,103.148
7	202.8571	87.14286	0	0	6,279.828
8	300	200	0	0	10,066.360
					74,089.544

Table-5. Comparison of cost value with other existing methods.

Method	Overall generation cost($)		
	Best	Averag e	Worst
Improved Lagrangian relaxation [13]	75,232	--	--
A. SMP [14]	74,812	74,877	75,166
Lagrangian relaxing & Particle swarm optimization [13]	74,808	--	--
Binary Differential evolution [15]	74,676	--	--
Two Layer Particle swarm optimization (TLPSO) [16]	74,476	74,500	74,675
Harmony Search Algorithm	74,089	74,585	74,675.11

The obtained optimal value is made in comparison with the literature methods shown in Table-5. Optimal value achieved using harmony search algorithm is better compared with existing methods which can be illustrated in Table-5. The total cost using HAS is 1.519 percent less compared with high optimal cost obtained using improved Lagrangian relaxation method.

5. CONCLUSIONS

The harmony search algorithm is applied on four unit thermal system with varying initial status of on/off time. The tuning parameters are considered in achieving a better optimal value of cost. The total cost function achieved a better optimal value and made a comparison with the existing methods. By varying the initial status the commitment of third and fourth thermal unit is low which is beneficial for the cost reduction.

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