An Improved Harmony Search Algorithm for solved the Combined Heat and Power Economic Dispatch

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Abstract: The Harmony Search (HS) algorithm is a population-based meta-heuristic optimization algorithm. This algorithm is inspired by the music improvisation process in which the musician searches for harmony and continues to polish the pitches to obtain a better harmony. Although several variants of the HS algorithm have been proposed, their effectiveness in dealing with diverse problems is still unsatisfactory. The performances of these variants mainly depend on the selection of different parameters of the algorithm. This paper develops an improved harmony search (IHS) algorithm for solving optimization problems. IHS employs a novel method for generating new solution vectors that enhances accuracy and convergence rate of harmony search (HS) algorithm. The IHS algorithm has been successfully applied to various benchmarking and standard engineering optimization problems. The optimal utilization of multiple combined heat and power (CHP) systems is a complicated problem that needs powerful methods to solve. This paper presents an improved harmony search (IHS) algorithm to solve the combined heat and power economic dispatch (CHPED) problem. In this paper the impacts of constant parameters on harmony search algorithm are discussed and a strategy for tuning these parameters is presented. Numerical results reveal that the proposed algorithm can find better solutions when compared to HS and other heuristic or deterministic methods where IHS algorithm is a powerful for will be effective in the problems of CHPED.

Keywords: Combined Heat and Power Economic Dispatch; Improved Harmony Search Algorithm; optimization; cogeneration.

1. Introduction

Increasing demand in the use of cogeneration systems that simultaneously produce heat and power is quite remarkable. Combined heat and power generation unit with industrial, commercial and residential applications is an efficient energy resource providing environmental advantages over other forms of conventional energy supply. Utilization of cogeneration units besides conventional power generating units and heat-only units to satisfy heat and electricity demands in an economical manner emphasizes on the need to combined heat and power economic dispatch (CHPED). In the pure economic dispatch problem, power demand is only taken and distributed on in-service generating units. In the CHPED problem, heat demand is also considered and mutual interdependency of heat and power production in cogeneration units introduces more complexity in the problem.

In the CHPED problem, it is tried to find economical optimum solution considering the mentioned complexity of the constraints. Indeed, the purpose of the problem is to specify the output of the units to satisfy heat and power demands with minimum fuel cost [1]. Recently, in order to make numerical methods more convenient for solving the CHPED problems, modern optimization techniques [2], [3] have been successfully employed to solve the CHPED problem as a non-smooth optimization problem. A global optimization technique known as the harmony search (HS) is one of these modern techniques [4].

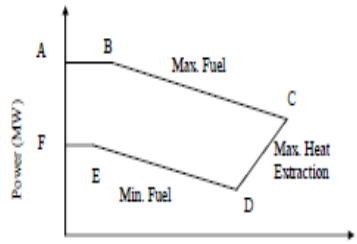
In this paper, we propose a novel approach for solving the CHPED problem using an improved harmony search (IHS) algorithm. The CHPED system based on the conventional power units, cogenerations units and the heats only units. The Systems data containing valve- point effects coefficients of fuel cost equations and B loss coefficients are obtained from Basu [5]. Numerical results obtained with the proposed IHS approach were compared with classical HS method and

Received: May 14th, 2018. Accepted: June 30th, 2019
DOI: 10.15676/ijeei.2019.11.2.14

other optimization results reported in literature. The remainder of this paper is organized as follows. Section 2 explains the formulation of the CHPED problem. In Section 3 the classical HS and the proposed IHS are described. Simulation results of IHS are presented and compared with HS and other algorithms in Section 4. Lastly, Section 5 outlines our conclusions.

2. CHPED problem formulation

The propose CHPED problem is an optimization problem, but it is consider some types of produce units such as pure heat units, combined power and heat (co-generation) and conventional power units. The co-generation is role to produce heat and power with feasible operation region according to "Figure. 1", where the boundary curve ABCDEF determines the feasible region [2], [8]. Along the boundary there is a trade-off between power generation and heat production from the unit. It can be seen that along the curve AB the unit reaches maximum output power. In contrast, the unit reaches maximum heat production along the curve CD [9]. Therefore, power generation limits of cogeneration units are the combined functions of the unit heat production and vice versa [4], [6], [7].



Figureure 1. Typical heat-power feasible region for CHP units

Mathematically, problem is formulated as "(1)" [10]-[11], [12]:

$$\text{Minimize } F_{\text{fuel}} = \sum_{i=1}^{N_p} f_i(P_i) + \sum_{j=1}^{N_c} f_j(P_j, h_j) + \sum_{k=1}^{N_h} f_k(h_k) \quad (1)$$

Subject to: Power production equilibrium constraint

$$\sum_{i=1}^{N_p} P_i + \sum_{j=1}^{N_c} P_j = P_D + P_L \quad (2)$$

Heat production equilibrium constraint

$$\sum_{j=1}^{N_c} h_j + \sum_{k=1}^{N_h} h_k = H_D \quad (3)$$

The capacity limits of each unit

$$P_i^{min} \le P_i \le P_i^{max} \quad , i = 1,2,\dots,Np \quad (4)$$

$$P_j^{min}(h_j) \le P_j(h_j) \le P_j^{max}(h_j) \quad , j = 1,2,\dots,Nc \quad (5)$$

$$h_j^{min}(P_j) \le h_j(P_j) \le h_j^{max}(P_j) \quad , j = 1,2,\dots,N \quad (6)$$

$$h_k^{min} \le h_k \le h_k^{max} \quad , k = 1,2,\dots,Nh \quad (7)$$

Where $f_i(P_i), f_j(P_j, h_j), f_k(h_k)$ are the respective fuel cost functions of power-only unit, CHP unit and heat-only unit, these cost functions are usually smooth quadratic, however, to model more realistic cost of units, the valve-point effects need to be considered. P_i, P_j, are the power generation of power-only and CHP units respectively; h_j, h_k, are heat production of CHP and heat-only units, respectively ; N_p, N_c, N_h, are the respective numbers of the above three kinds of units. WhereP_D, H_D are the power and heat demand of system; P_L is the system power transmission loss that can be calculated by B-coefficient loss formula as shown in the following:

$$P_L = \sum_{i=1}^{N_p+N_c} \sum_{j=1}^{N_p+N_c} P_i B_{ij} P_j \quad (8)$$

Where B_{ij} is the loss coefficient for network branch connected between power generation units i and j.

3. Improved Harmony Search algorithm

A. Harmony Search algorithm

Recently, Geem and al [14], proposed a new HS meta-heuristic algorithm that was inspired by musical process of searching for a perfect state of harmony. The harmony in music is analogous to the optimization solution vector, and the musician's improvisations are analogous to local and global search schemes in optimization techniques. The HS algorithm does not require initial values for the decision variables. Furthermore, instead of a gradient search, the HS algorithm uses a stochastic random search that is based on the harmony memory considering rate and the pitch adjusting rate so that derivative information is unnecessary [15].

In the HS algorithm, musical performances seek a perfect state of harmony determined by aesthetic estimation, as the optimization algorithms seek a best state (i.e. global optimum) determined by objective function value. It has been successfully applied to various optimization problems in computation and engineering fields [15].

The optimization procedure of the HS algorithm consists of Steps 1–5, as follows [16]:

Step 1: Initialize the optimization problem and algorithm parameters.

Step 2: Initialize the harmony memory (HM).

Step 3: Improvise a new harmony from the HM.

Step 4: Update the HM.

Step 5: Repeat Steps 3 and 4 until the termination criterion has been satisfied.

The detailed explanation of these steps can be found in [14, 4] which are summarized in the following:

Step1. Initialize the optimization problem and HS Algorithm parameters.

First, the optimization problem is specified as follows:

Minimize f(x) subject to $x_i \epsilon X_i$, $i = 1, \dots, N$.

Where f(x) is the objective function, x is the set of each decision variable (x_i); X_i is the set of the possible range of values for each design variable (continuous design variables), that is, $x_{i\,lower} \leq X_i \leq x_{i\,upper}$, where $x_{i\,lower}$ and $x_{i\,upper}$ are the lower and upper bounds for each decision variable; and N is the number of design variables. In this context, the HS algorithm parameters that are required to solve the optimization problem are also specified in this step. The number of solution vectors in harmony memory (HMS) that is the size of the harmony memory matrix, harmony memory considering rate (HMCR), pitch adjusting rate (PAR), and the maximum number of searches (stopping criterion) are selected in this step. Here, HMCR and PAR are parameters that are used to improve the solution vector. In this context, both are defined in Step 3.

Step2. Initialize the harmony memory (HM). The harmony memory (HM) is a memory location where all the solution vectors (sets of decision variables) are stored. In Step 2, the HM matrix, shown in "(9)", is filled with randomly generated solution vectors using a uniform distribution, where:

$$HM = \begin{bmatrix} x_1^1 & x_2^1 & \dots & x_N^1 \\ x_1^2 & x_2^2 & \dots & x_N^2 \\ \vdots & & & \\ x_1^{HMS} & x_2^{HMS} & \dots & x_N^{HMS} \end{bmatrix} \begin{matrix} \Rightarrow f(x^1) \\ \Rightarrow f(x^2) \\ \Rightarrow \dots\dots\dots \\ \Rightarrow f(x^{HMS}) \end{matrix} \quad (9)$$

Step3. Improvise a new harmony from the HM. A new harmony vector $x' = (x_1' \ldots x_N')$ is generated based on three rules: (a) memory consideration, (b) pitch adjustment, and (c) random selection. Generating a new harmony is called 'improvisation'.

In the memory consideration, the value of the first decision variable (x_1') for the new vector is chosen from any value in the specified HM range (x_1',.., x_N^{HMS}). Values of the other decision variables (x_2',…, x_N^{HMS}) are chosen in the same manner. The HMCR, which varies between 0 and 1, is the rate of choosing one value from the historical values stored in the HM, while (1-HMCR) is the rate of randomly selecting one value from the possible range of values.

$$x_i' \leftarrow \begin{cases} x_i' \in \{x_i^1; x_i^2; \ldots; x_i^{HMS}\} w.p. HMCR \\ x_i' \in X_i, \ldots\ldots\ldots\ldots\ldots\ldots w.p (1 - HMCR) \end{cases} \quad (10)$$

After, every component obtained by the memory consideration is examined to determine whether it should be pitch-adjusted. This operation uses the PAR parameter, which is the rate of pitch adjustment as follows:

$$Pitch\ adjuseting\ decision\ for\ x_i' \leftarrow \begin{cases} yes\ \ with\ probability\ PAR \\ NO\ \ with\ probability\ (1 - PAR) \end{cases} \quad (11)$$

The value of (1 -PAR) sets the rate of doing nothing. If the pitch adjustment decision for x_i' is yes, then x_i' is replaced as follows:

$$x_i' \leftarrow x_i' \pm r.bw \quad (12)$$

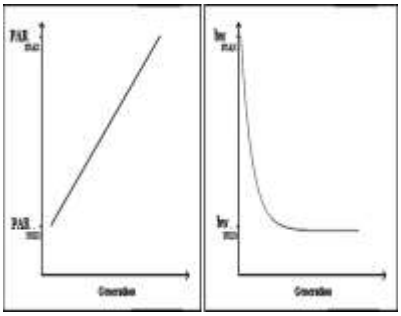
Where bw is an arbitrary distance bandwidth, r is a random number generated using uniform distribution between 0 and 1. In Step 3, HM consideration, pitch adjustment or random selection is applied to each variable of the New Harmony vector in turn.

Step4. Update the HM. If the new harmony vector, $(x_1', \ldots, x_N')$ is better than the worst harmony in the HM, judged in terms of the objective function value, the new harmony is included in the HM and the existing worst harmony is excluded from the HM.

Step5. Repeat Steps 3 and 4 until the termination criterion has been satisfied.

B. Proposed Improved HS algorithm

To improve the performance of the HS algorithm and eliminate the drawbacks lie with fixed values of HMCR and PAR, Mahdavi and al. [17] proposed an improved harmony search algorithm that uses variable PAR and bw in improvisation step. The IHS proposed in this work has exactly the same steps of classical HS with exception that Step 3, where the IHS dynamically updates PAR in which concepts from dispersed particle swarm optimization are adopted. The key difference between IHS and traditional HS method is in the way of adjusting PAR and bw to improve the performance of the HS algorithm and eliminate the drawbacks lies with fixed values of PAR and bw, IHS algorithm uses variables PAR and bw in improvisation step (Step 3). PAR and bw change dynamically with generation number as shown in "Figure. 2" and expressed as follow:



Figureure 2. Variation of PAR and bw versus generation number.

$$PAR(gn) = PAR_{min} + \frac{(PAR_{max} - PAR_{min})}{NI} \times gn \quad (13)$$

And

$$bw(gn) = bw_{max}.exp(c.gn) \quad (14)$$

$$c = \frac{Ln\left(\frac{bw_{min}}{bw_{max}}\right)}{NI} \quad (15)$$

Where:
PAR pitch adjusting rate for each generation,
PAR_{min} minimum pitch adjusting rate,
PAR_{max} maximum pitch adjusting rate,
NI number of solution vector generations,
gn generation number,
bw(gn) bandwidth for each generation,
bw_{min} minimum bandwidth,
bw_{max} maximum bandwidth.

This improvement introduces to HS algorithm makes that the algorithm tends towards the global optimum with more precision.

C. IHS algorithm for solved CHPED problems

Improved harmony search algorithm for solving CHPED problem is described below:
Let $X_i = [P_1, P_2, \dots, P_N, P_{N+1}, P_{N+2}, \dots, P_C, H_{N+1}, H_{N+2}, \dots, H_c, H_{C+1}, H_{C+2}, \dots, H_k]$ be the initial designating the i^{th} be the initial vector designating the i^{th} population to be evolved. The elements of X_i are the real power outputs of conventional thermal generators and cogeneration units and heat outputs of cogeneration units and heat-only units. The elements of X_i should satisfy the constraints given by "(2)" until "(7)". The IHS algorithm implemented to solve CHPED problem is stated in the following steps.

Step 1: Initialize the parameters HMS, HMCR, PAR_{min}, PAR_{Max}, bw_{min}, bw_{Max}, NI, gn=1
Step 2: Initialize harmony memory. Calculate the fitness value for all solution vectors in harmony memory.
Step 3: Improvisation process of harmony memory as mentioned in "(10)", with the parameters PAR and bw change dynamically with generation number as given by "(13)" until "(15)". Calculate the fitness value for the entire new improvised harmony/solution vectors.
Step 4: Select the best improvised solution out of entire new improvised solution vectors. Update the harmony memory if it is better than the worst harmony. Put gn = gn + 1.
Step 5: Stopping criterion if gn < NI if not repeat Steps 3 and 4 until the termination criterion has been satisfied.

4. Results and Analysis

In this section, the results of the simulations on two test systems are presented to evaluate the effectiveness of the proposed algorithm. The data of the test systems, the simulation results and eventually the comparison of the results of the proposed algorithm with the other methods in the literature will be provided in the field of convergence speed and solution quality. The proposed HIS algorithm program has been implemented on the MATLAB7.1 on PC (Intel®, Core (TM), i5-3230M, CPU 2.60 GHz, 2.60 GHz , with 4.00 Go RAM).

The parameters of the proposed IHS algorithm for all test cases are set as follows: harmony memory size (HMS) is equal to 6, harmony memory consideration (HMCR) is equal as 0.85 and the minimum and maximum pitch adjusting rate (PAR_{min}, PAR_{max})are equals to 0.45, 0.85 respectively , the minimum and maximum bandwidth (bw_{max}, bw_{max}) are equals as 0.001, 1

respectively. The fuel Cost is in "dollar ($)", heat output is in "megawatt thermal (MWth)", and power output is in "megawatt (MW)" in all the test systems.

A. Test system 1.

This is simple test system, proposed by [20], [21] includes 4 units which are one power-only unit, one heat-only unit and two cogeneration units, and it is the classical representation of simple CHPED problems and used to evaluate the algorithm in most literature of the CHPED problems. To compare the proposed algorithm with other typical algorithms, we choose the classical simple test system as the benchmark, where the power transmission loss and valve-point effects are ignored as the same as in all other literatures.

The fuel cost formulation of the four units is given:

- Power only units: $F_1(P_1) = 50P_1|\$$ (16)
- Cogeneration units:

$F_2(P_2, H_2) = 2650 + 14.5P_2 + 0.0345P_2^2 + 4.2H_2 + 0.03H_2^2 + 0.031P_2H_2|\$$ (17)

$F_3(P_3, H_3) = 1250 + 36P_3 + 0.0435P_3^2 + 0.6H_3 + 0.027H_3^2 + 0.011P_3H_3|\$$ (18)

- Heat only units: $F_4(H_4) = 23.4H_4|\$$ (19)

The test system1, has 6 decision variables (P_1, P_2, P_3, H_2, H_3, H_4), the domains of the decision variables are stated:

$P_1 \in [0,150]$, $P_2 \in [81, 274]$, $P_3 \in [40,125.8]$, $H_2 \in [0, 180]$, $H_3 \in [0,135.6]$, $H_4 \in [0, 2695.2]$.

The fitness function of the CHPED problem is formulated as:

$Min\{F_{total} = F_1(P_1) + F_2(P_2, H_2) + F_3(P_3, H_3) + F_4(H_4)\}$ (20)

Subjected to be equality constraints: $P_1 + P_2 + P_3 = P_D$ and $H_2 + H_3 + H_4 = H_D$ (21)

And the inequality constraints: $0 \le P_1 \le 150\ MW$ and $0 \le H_4 \le 2695.2\ MWth$ (22)

The Power demands (P_D) and heat demands (H_D) of the test system1 are 200MW and 115MWth, respectively. These feasible operation regions are depicted in "Figure 3" and "Figure 4", for first and second CHP units of the test system 1.

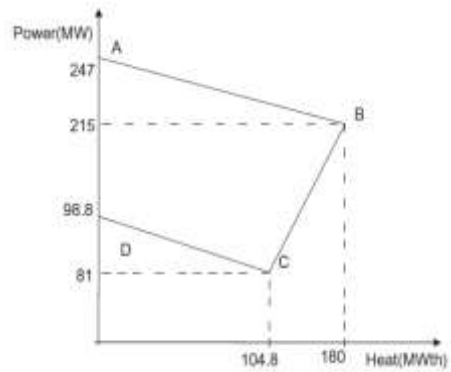


Figure 3. Feasible Operation region of the first CHP unit.

The cost convergence curve of the proposed method for the test system1 is depicted in "Figure 5". As can be seen in this Figure, the optimization algorithm converges to the lowest optimal from 100 iterations.

The results of IHS algorithm proposed and its comparison with the classical HS algorithm [23], Genetic Algorithm (GA) [19] and Augmented Lagrange Hopfield Network (ALHN) [20] are provided in table 1. The optimal solution of this test system1 attained by the IHS algorithm proposed is 9179.5$ for 200 iteration. According to the results, the proposed algorithm attains the optimum solution for the problem compared with the other methods.

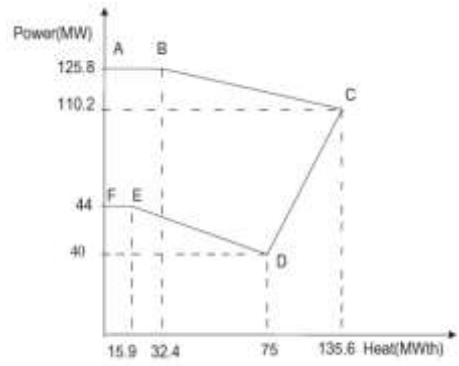


Figure 4. Feasible Operation region of the second CHP unit.

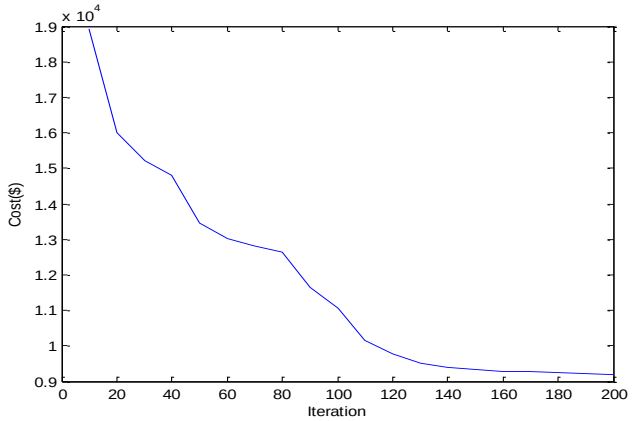


Figure 5. The Cost convergence curve for test system1.

Table 1. Comparison the best results of its algorithm with HS algorithm and other methods for test system1

Method	IHS	HS	ALHN	GA
P1(MW)	5.1662	0.887	0.0	0.0
P2(MW)	49.00997	46.0268	159.9994	159.23
P3(MW)	100.1671	103.32	40.00	39.95
H2(MWh)	9.8193	1.7629	39.9993	40.77
H3(MWh)	0.3724	1.7952	75	75.06
H4(MWh)	4.7797	14.3787	0.0	0.0
Cost($)	9179.5	9230.2	9257.05	9267.2

B. Test system2

This simple test system case proposed by [8], [13] consists of 4 power only-units, two cogeneration units and one heat-only unit, and it is a classical representation of sophisticated CHPED problems and used to evaluate the algorithms in most literature. In this test system, the valve-point effects of the power unit and power net transmission losses in the CHPED problem are considered as the same as in all the other referred literatures [5].

The fuel cost formulation of the four power-only units, two cogeneration units, and one heat unit are given:

Power only units:

$$F_1(P_1)25 + 2P_1 + 0.008P_1^2 + \left|100\,sin\{0.042(P_1^{min} - P_1)\}\right|\$ \quad 10 \le P_1 \le 75\ MW \tag{23}$$

$$F_2(P_2) = 60 + 1.8P_2 + 0.003P_2^2 + \left|140\,sin\{0.04(P_2^{min} - P_2)\}\right|\$ \ 20 \le P_2 \le 125\ MW \tag{24}$$

$$F_3(P_3) = 100 + 2.1P_3 + 0.0012P_3^2 + \left|160\,sin\{0.038(P_3^{min} - P_3)\}\right|\$ \ 30 \le P_3 \le 175\ MW \tag{25}$$

$$F_4(P_4) = 120 + 2P_4 + 0.001P_4^2 + \left|180\,sin\{0.037(P_4^{min} - P_4)\}\right|\$ \quad 40 \le P_4 \le 250\ MW \tag{26}$$

- Cogeneration units:

$$F_5(P_5, H_5) = 2650 + 14.5P_5 + 0.0345P_5^2 + 4.2H_5 + 0.03H_5^2 + 0.031P_5H_5|\$ \tag{27}$$

$$F_6(P_6, H_6) = 1250 + 36P_6 + 0.0435P_6^2 + 0.6H_6 + 0.027H_6^2 + 0.11P_6H_6|\$ \tag{28}$$

- Heat only units:

$$F_7(H_7) = 950 + 2.0109H_7 + 0.038H_7^2|\$ \quad 0 \le H_7 \le 2695.2\ MWth \tag{29}$$

The test system2, has 9 decision variables (P_1, P_2, P_3, P_4, P_5, P_6, H_5, H_6, H_7), the domains of decision variables are stated:

$P_1 \in [10,75]$, $P_2 \in [20,125]$, $P_3 \in [30,175]$, $P_4 \in [40,250]$, $P_5 \in [81,247]$, $H_5 \in [0,180]$, $P_6 \in [40,125.8]$, $H_6 \in [0,135.6]$, $H_7 \in [0,60]$.

The fitness function of the CHPED problem is formulated as:

$$Min\ \{F = F_1(P_1) + F_2(P_2) + F_3(P_3) + F_4(P_4) + F_5(P_5, H_5) + F_6(P_6, H_6) + F_7(H_7)\} \tag{30}$$

Subjected to be equality constraints:

$$P_1 + P_2 + P_3 + P_4 = P_d + P_L \ \text{MW} \qquad H_5 + H_6 + H_7 = H_d \ \text{MWth} \tag{31}$$

Where:

$$P_L = \sum_{i=1}^{\beta}\sum_{j=1}^{\beta} P_i B_{ij} P_j \tag{32}$$

$$\text{For} \quad B = \begin{bmatrix} 49 & 14 & 15 & 15 & 20 & 25 \\ 14 & 45 & 16 & 20 & 18 & 19 \\ 15 & 16 & 39 & 10 & 12 & 15 \\ 15 & 20 & 10 & 40 & 14 & 11 \\ 20 & 18 & 12 & 14 & 35 & 17 \\ 25 & 19 & 15 & 11 & 17 & 39 \end{bmatrix} * 10^{-7} \tag{33}$$

The power demands (P_D) and heat demands (H_D) of the test system1 are 600MW and 150MWth, respectively.

And the inequality constraints:

$$g_1 = 1.781914894H_5 - P_5 - 105.7446809 \le 0 \tag{34}$$

$$g_2 = 0.1777777784H_5 + P_5 - 247.0 \le 0 \tag{35}$$

$$g_3 = -0.169847328H_5 - P_5 + 98.8 \le 0 \tag{36}$$

$$g_4 = 1.158415842H_6 - P_6 - 46.88118818 \le 0 \tag{37}$$

$$g_5 = 0.151162791H_6 + P_6 - 130.6976744 \le 0 \tag{38}$$

$$g_6 = -0.06768189H_6 - P_6 + 45.07614213 \le 0 \tag{39}$$

The convergence curve of the proposed method for the test system2 is depicted in "Figure 6". As can be seen in this Figure, the optimization algorithm converges to the lowest optimal from 300 iterations.

The results of IHS algorithm proposed and its comparison with the classical HS algorithm [24], Artificial bee colony optimization (ABC) [8] and Bee colony optimization (BCO) [13] are provided in table 2. The optimal solution of this test system2 attained by the IHS algorithm proposed is 9303.3$ for 800 iteration. According to the results, the proposed algorithm attains the optimum solution for the problem compared with the other methods.

Also from table 2, it can be observed that the CPU time of IHS algorithm is equal as 2.42 second, and the power net transmission loss is equal as 3.020 MW.

Therefore, the results of the fuel cost, the power net transmission and the CPU time of HIS proposed are much less than that of the classical HS and other methods.

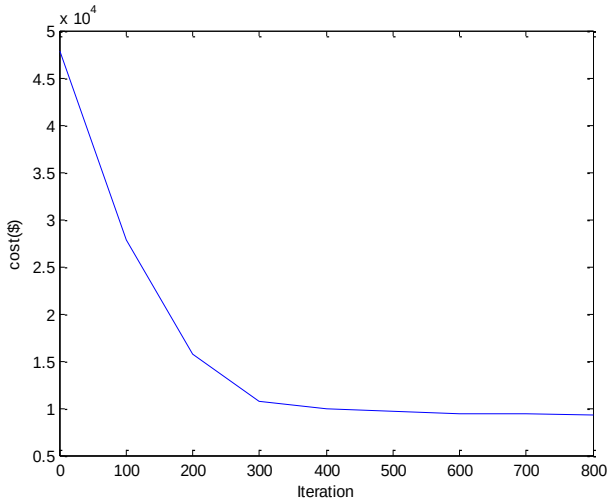


Figure 6. Cost convergence curve for test system2

Table 2. Comparison the best results of IHS algorithm with HS algorithm and other methods for test system2

Method	IHS	HS	ABC	BCO
P_1 (MW)	13.9698	13.6214	58.7117	43.9457
P_2 (MW)	20.2684	21.5668	98.5398	98.5888
P_3 (MW)	37.3182	33.7532	112.6735	112.930
P_4 (MW)	41.3764	41.2658	209.8158	209.779
P_5 (MW)	96.7436	95.5091	81.00	98.8000
P_6 (MW)	40.9035	42.1660	40.00	4.000
H_5 (MWth)	16.1310	19.9656	23.1014	12.0974
H_6 (MWth)	75.0681	75.8909	72.2437	78.0236
H_7 (MWth)	0.89750	0.2033	54.6549	59.879
P_L (MW)	3.020	3.7854	2.88	8.0384
Cost ($)	9303.3	9367.7	10314	10317
Time (s)	2.43	2.53	4.981	5.1563

From results simulation of test system1, and test system2, the Improved Harmony Search algorithm (IHS) proposed obtains global optimal fuel cost than the classical HS algorithm and other methods. The reason for this phenomenon is that the PAR and bw parameters are dynamically adjusted, where as in classical HS algorithm the PAR and bw parameters are fixed. Therefore, the conclusion can be drawn that IHS algorithm is an effective way to solving the CHPED problem.

5. Conclusions

In this paper, improved harmony search algorithm is proposed to solve the combined heat and power economic dispatch (CHPED) problem was presented. We suggested solving CHPED using the proposed IHS algorithm for two standard test systems were presented to demonstrate

the effectiveness and robustness of this algorithm. In all cases, the solutions obtained using IHS algorithm were better than those obtained by a simple HS algorithm and other methods.

6. References

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