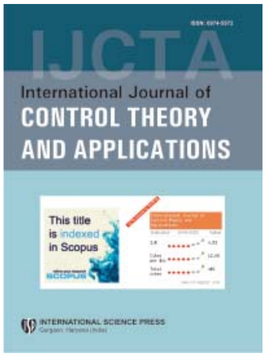

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Dynamic Economic Dispatch Scenario using Harmony Search Technique

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Abstract : In the recent era the demand of the power system is highly stochastic in nature and the demand is increasing day by day for which cost of generation is to be controlled according to the demand around all the hours in a day. Maintaining least cost for generated power is the responsibility of the power utility and it must match the demand. Hence, cost-effective operation of system depends on the total demand being applicably pooled amid generating units with concern to curtail the gross generation cost. Dynamic Economic dispatch being constrained optimization, optimal tool plays an important role to control the cost and governs optimal setup of power demands over a definite period of time. This method is used to minimize the cost function and optimal settings of generator units with projected load demand over a certain interval of time. The major objective is to maintain economical operation of power system, within its constraint. In this paper a random search technique known as Harmony search algorithm is used to optimize the generating cost of an IEEE 10 unit generating system. The system is studied for 24 hours on hourly basis for dynamic load dispatch.

Keywords: *Dynamic Economic Dispatch (DED), Sysytem Constraint, Harmony Search (HS).*

1. INTRODUCTION

The financial plan of power provider, the prime practical setup and planning of electrical power generation system is vital to the power production [1]. With gigantic interconnected power system, the mash of vitality and persistent increment in costs, it is required to minimize operational charges of energy provided. Reducing the fuel cost for connected units can decrease operational expense. Financial aspects of load to be dispatched by the connected units are divided to accomplish ideal operational cost. The ideal working expense is to be acquired by considering the limitation on system operation to affirm the system constraints, accordingly maintaining a strategic reserve from the breakdown of system subjected to unexpected problems. The issue addressed in the paper is the test of the right allotment of load to the accessible units to achieve the ideal load adjusts [2]. The capacity of cost for individual units has been described by quadratic capacity ignoring the valve point impacts in the DED. DED situation considering valve direct impact leads toward non-smooth advancement issue having complex qualities.

Dynamic economic dispatch (DED) works by on-line planning of generators by finding the prime era, there by accomplishing requested supply adjust over a given interim of time with ideal working expense in various system considering different constraints of operation. Ramp rate limitations may influence the operational choice on hourly basis. Heuristic technique approaches [3] are simple to apply with faster computational performance at optimum price [4]. Different upgrading strategy is utilized to make a solution of the DED issue, such as Particle Swarm Optimization (PSO) [5], Gravitational Search Algorithm (GSA) [6], Genetic Algorithms (GA) [7], Simulated Annealing (SA) [8] and so forth. However, the performance of these techniques is significantly influenced by the parameters. This paper shows an optimum solution by applying the HS technique than some other technique.

2. PROBLEM FORMULATION

The DED is formulated as a nonlinear and complex optimization problem considering several constraints for the IEEE 10 unit generator system.

Let C*i* be the charge of generating energy by a unit. Therefore, cost for the *i* units be

$$C = \sum_{i=1}^{N} \tag{1}$$

$$\text{Min } C(P_g) = \sum_{i=1}^{NT} \sum_{i=1}^{NG} C(P_{it}) \tag{2}$$

Where,

$$C(P_{it}) = a_i P_{it}^2 + b_i P_{it} + c_{it} \tag{3}$$

NT = Total time period, *ai*, *bi* & *ci* are the co-efficient,

NG = No. of generated unit Demand Load Balancing Constraint

$$P_D = \sum_{i=1}^{N} P_{gi} + P_L \tag{4}$$

P_D = Load Demand,

P_{gi} = Total Generated load at different time,

P_L = Transmission Loss

$$P_L = \sum_{j=1}^{n} \sum_{i=1}^{n} P_{it} B_{ij} P_{it} + \sum_{i=1}^{n} B_{10} P_{it} + B_{00} \tag{5}$$

Generator Constraint The output power of the generator maintained within the upper and lower bound [3].

$$P\min < P < P\max \tag{6}$$

The online action for generating units is constrained by Ramp rate bounds. These bounds have an impact on the operational decisions. The current scheduling may disturb the future scheduling as generation increases due to ramp rate bounds.

$$\begin{cases} P_{i,t} - P_{i,t-1} \le UR_i \\ P_{i,t-1} - P_{i,t} \le DR_i \end{cases}$$

i = 1, 2, 3 ..., N.

t = 2, 3, ...T

3. HARMONY SEARCH ALGORITHM

Currently, Geem et al. proposed a music inspired HS meta-heuristic algorithm for searching actual process of harmony. Harmony in music is analogous to the optimization process and the process of improving the harmony. HS algorithm improvises the process to optimize the global and local systems. The lot of a meta heuristically algorithm proposed base on population such as evolutionary algorithms which contains Genetic algorithm, Evolutionary Strategies, DE algorithm, HS algorithm, etc. And the algorithms based on swarm which contains, Particle Swarm Optimization, Bees Algorithms, Ant Colony Optimization, etc. over the last period. The opening values for the decision variables are not required in this algorithm. This algorithmic process uses a stochastic based search process on the memory of the harmony considering rate and adjusting rate of the pitch to overlook derived information [9, 10]. Processes and performances on music require a ideal state of harmony and strong minded by artistic estimation and optimization procedures produce the finest state, determined by objective function value. Harmony search makes the process as the following [11]

1. Each decision variable is referred from each musician.
2. Decision variable's value range is referred from Musical instrument's pitch.
3. The solution vector at certain iteration is referred from harmony of music at a certain time,
4. The objective function is referred from Audience's aesthetics.

3.1. Harmony Search Technique steps

1. **Initialization of Harmony Memory (HM):** HM created [11] by considering solution matrix with dimensions as that in HMS. All the elements in harmony memory matrix signify one solution. Here the solutions are stochastically created and again arranged by ordering in a reverse way to HM, constructed on their values depending upon the objective function. like

$$f(a_1) \le f(a_2) \le f(a_3) \dots \le f(a_{HMS})$$

$$HM = \begin{bmatrix} a_1^1 & a_2^1 \cdots & a_N^1 \\ a_1^2 & a_2^2 \ddots & a_N^2 \\ a_1^{HMS} & a_2^{HMS} & a_N^{HMS} \end{bmatrix}$$

2. **Improvise New Harmony :** New Harmony vector is improvised by HS process,

$$a_i' = a_1', a_2', a_3', \dots \dots \dots, a_N'$$

Initialization of HMCR, PARmax, and PARmin is processed and determine whether in the limit. The new value is updated,

$$a_i' \leftarrow \begin{cases} a_i' \in \{a_i^1, a_i^2, a_i^3, \dots\dots a_i^{HMS}\} \; w.p \text{ HMCR} \\ a_i' \in \text{A}i \qquad\qquad w.p\ (1 - \text{HMCR}) \end{cases}$$

By tuning the entire decision variable, a search process is added to the New Harmony vector.

$$a_i' = a_1', a_2', a_3', \dots \dots \dots, a_N' \text{ from HM taking PAR operator.}$$

$$a_i' \leftarrow \begin{cases} \text{Pitch adjusted } w.p \text{ PAR} \\ \text{No change } w.p\ (1 - \text{PAR}) \end{cases}$$

Any produced arbitrary number rd ε [0, 1] is inside possibility limit of PAR, a new assessment variable (a_i') is attuned on the given equation:

$$a_i' \;=\; (a_i' + rd()) \times bw$$

Here, b is a random bandwidth of the distance.

3. **Updating the harmony memory:** The HM was updated by the new vector created $a_i' = a_1', a_2', a_3',\ldots\ldots, a_N'$, and each objective function is considered for New Harmony vector $f(a`)$. If the objective function value of new vector is good than the previous harmony vector, then it stored in HM Otherwise, this new vector is overlooked.

4. **Checking the stopping condition:** The process of iteration in the above steps is finished when the extreme number of iteration is touched. Lastly, the harmony memory vector with best value is selected and is considered as finest solution to the problem.

Figure 1: Shown below is the flowchart of the harmony search algorithm

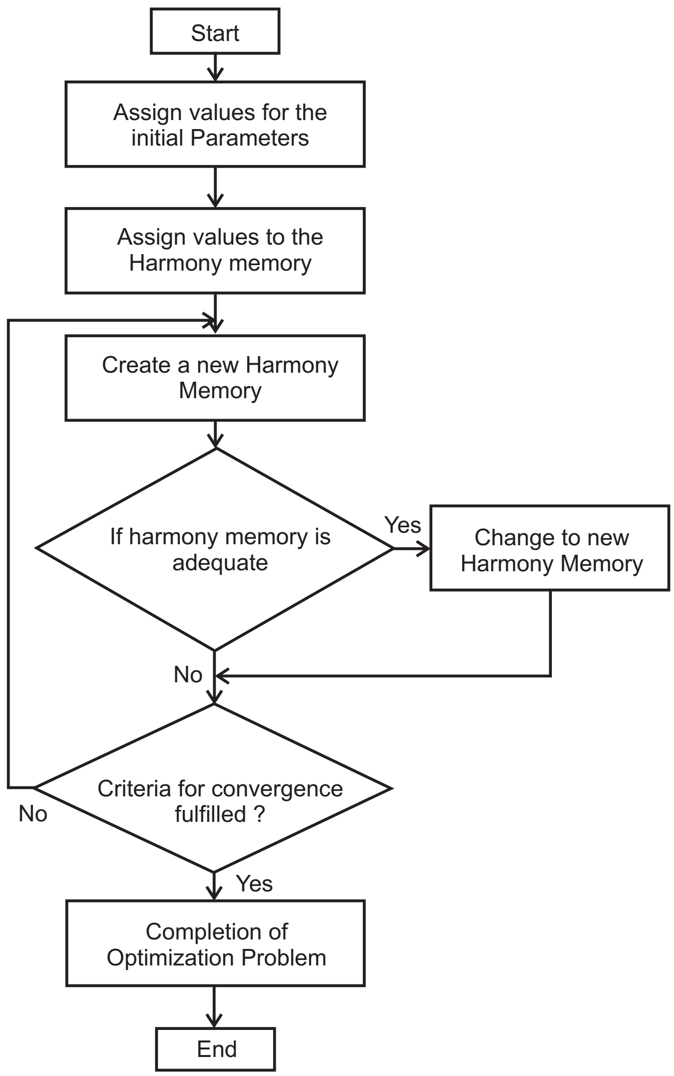

Figure 1: Flow chart for Harmony search

4. RESULT AND ANALYSIS

The dynamic load dispatch with load variation in a dynamic sequence is analysed by some optimization technique for the IEEE 10 unit system. The output power for the hourly dispatched corresponding to the demand for the Harmony search technique and Invasive weed optimisation technique was shown in the Table I and Table II respectively. The Harmony Search technique is applied for the System and the total cost based on hourly load dispatch is obtained and is presented in Table III. After the dynamic load dispatch was obtained with an implementation of HS technique the economics of the solution dispatch obtained is economic than the other technique applied to the system [12, 13]. Fig .2 shows the convergence curve by applying the Harmony Search Technique and Invasive weed optimization technique with the iteration taken. It was identified that harmony search technique is giving optimum value with a faster converging time.

Table 1
Generator schedule for 24 hours Using HS Technique (Hourly Load Dispatch)

Hour	*P1, MW*	*P2, MW*	*P3, MW*	*P4, MW*	*P5, MW*	*P6, MW*	*P7, MW*	*P8, MW*	*P9, MW*	*P10, MW*
1	227.444	226.031	86.345	63.195	126.547	125.824	56.535	47.478	21.596	55
2	225.933	222.307	81.775	60.011	122.429	123.839	91.646	82.802	44.253	55
3	224.225	221.919	186.515	120.077	125.776	125.218	93.285	84.543	21.437	55
4	303.279	223.313	188.512	125.101	126.721	124.767	127.190	85.607	46.503	55
5	300.986	310.446	194.098	117.248	122.721	120.394	126.929	84.385	47.788	55
6	304.733	309.812	306.866	123.575	171.021	124.087	125.255	75.815	31.831	55
7	380.970	310.699	292.707	120.731	173.736	124.389	128.660	85.174	29.929	55
8	381.429	399.268	293.122	122.102	172.895	121.820	118.877	85.250	26.231	55
9	456.292	397.083	300.316	180.742	171.907	125.194	127.247	85.043	25.173	55
10	456.263	396.408	296.789	244.523	221.341	132.542	128.673	116.336	24.121	55
11	460.113	457.939	315.184	241.171	225.722	128.276	127.948	86.739	47.902	55
12	457.327	458.344	322.677	295.167	220.151	150.428	128.747	86.850	45.304	55
13	457.327	458.344	322.677	295.167	220.151	150.428	128.747	86.850	45.304	55
14	381.476	395.872	292.044	239.156	174.386	122.460	128.16	84.158	51.281	55
15	377.881	314.454	293.415	240.036	147.092	121.778	92.983	85.586	47.769	55
16	302.172	308.528	182.893	182.058	173.728	120.070	93.541	84.508	51.497	55
17	301.913	308.456	182.201	179.520	121.145	104.660	95.683	85.055	46.362	55
18	305.061	308.827	290.814	177.358	172.472	122.029	125.901	48.740	21.794	55
19	379.640	309.029	307.666	240.756	127.491	124.644	118.192	84.796	28.782	55
20	457.245	459.938	338.439	169.950	221.770	130.392	129.257	86.585	23.421	55
21	454.199	396.598	296.088	121.651	215.812	122.257	128.324	84.518	49.549	55
22	379.515	396.723	194.246	118.165	171.137	110.843	92.429	84.574	25.363	55
23	303.133	311.017	191.319	119.540	124.157	58.024	92.048	47.786	29.971	55
24	227.495	309.460	87.074	61.621	119.431	114.732	91.575	83.735	33.874	55

Table 2
Generator schedule for 24 hours Using IWE Technique (Hourly Load Dispatch)

Hour	*P1, MW*	*P2, MW*	*P3, MW*	*P4, MW*	*P5, MW*	*P6, MW*	*P7, MW*	*P8, MW*	*P9, MW*	*P10, MW*
1	226.63	135.86	186.94	72.91	73.12	123.37	56.86	85.31	20.00	55
2	226.62	135.00	167.54	118.74	122.82	122.44	56.53	85.31	20.00	55
3	226.62	215.00	152.27	118.39	172.68	156.20	56.53	85.31	20.00	55
4	303.25	222.27	202.44	163.90	172.89	124.40	56.53	85.31	20.00	55
5	303.25	285.15	177.30	178.55	222.60	96.31	56.53	85.31	20.00	55
6	379.87	313.19	192.64	176.10	172.71	122.45	56.53	114.92	44.60	55
7	303.25	393.19	224.83	226.10	174.27	131.61	58.30	115.45	20.00	55
8	303.25	396.80	261.62	241.17	172.73	122.38	88.30	85.45	49.31	55
9	379.87	396.80	304.68	241.25	222.60	122.45	93.06	88.27	20.01	55
10	379.87	460.00	303.86	256.50	224.97	123.64	99.87	118.27	50.01	55
11	456.50	396.80	306.98	300.00	228.90	132.20	129.61	120.00	20.03	55
12	456.50	459.81	308.26	299.62	222.60	122.45	129.59	116.14	50.03	55
13	379.87	460.00	313.03	296.56	172.73	127.01	129.59	86.14	52.06	55
14	379.87	396.80	321.70	246.56	128.55	128.46	129.69	115.31	22.06	55
15	303.25	340.52	312.59	230.76	172.75	126.23	129.59	85.31	20.00	55
16	303.17	309.41	258.22	180.76	122.81	122.28	127.03	55.31	20.00	55
17	303.25	309.69	187.29	180.83	126.29	123.61	97.03	47.00	50.00	55
18	379.87	316.80	189.49	185.98	172.73	136.72	93.06	47.00	51.33	55
19	379.87	396.80	243.97	235.98	172.77	123.06	100.21	47.00	21.33	55
20	456.79	399.39	301.27	254.01	222.63	125.99	129.70	77.00	50.22	55
21	456.50	388.42	253.54	229.14	222.57	122.02	129.59	47.00	20.22	55
22	379.87	308.43	185.62	180.26	172.73	122.45	129.51	47.00	47.13	55
23	303.25	228.43	142.35	169.86	122.87	111.68	99.51	47.00	52.05	55
24	303.25	171.23	191.31	120.71	88.31	61.68	93.45	47.00	52.06	55

Table 1 and Table 2 is presenting the generation of power at different hour of a day to match the demand considering the various constraint by Harmony search technique and Invasive weed optimisation technique respectively. Comparing the cost of dynamically economic dispatch same numbers of iterations Harmony search technique is giving the optimum cost for the generation considering the constraint is shown in Table 3.

Table 3
Cost Comparison

S.No.	*Methods*	*Cost ($)*
1.	Harmony Search Technique	1020273.682345
2.	Modified Invasive Weed Optimization [12]	1035630.223367
3.	Invasive Weed Optimization	1039743.254276
4.	Deterministically guided PSO [13]	1049167.000000

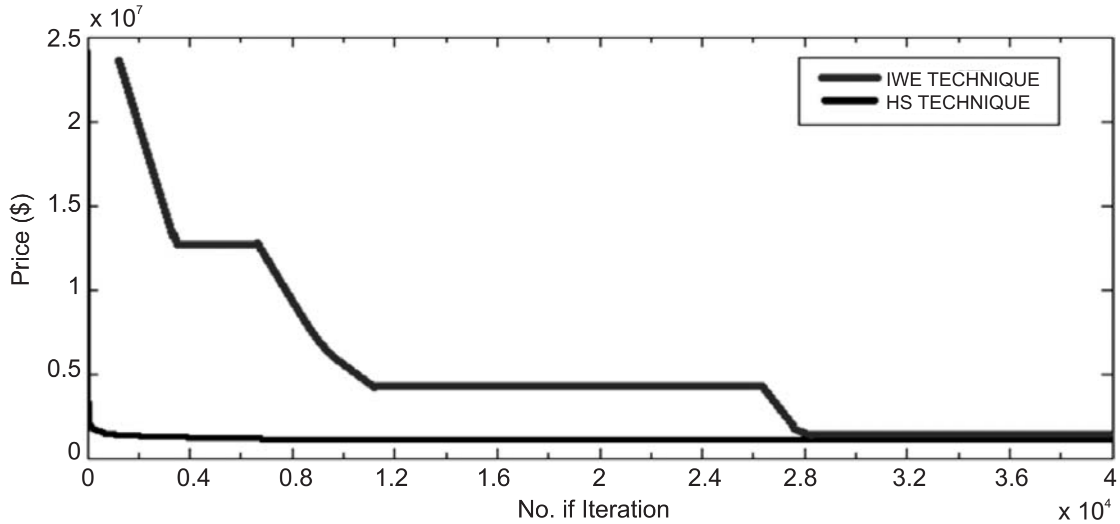

Figure 2: Convergence curve for the HS technique

5. CONCLUSION

Using Harmony Search technique in Dynamic Economic Dispatch the result is optimized and the result is also satisfying all the constraints. The main focus of this paper is to survey and summarize the applications of HS for solving the DED problems. It was found to converge to the optimum result at a faster rate. The method requires primitive mathematical operators, so is computationally inexpensive in terms of both memory requirements and speed. In the Harmony search technique, the optimal solution is obtained by successive iteration. In Table III the total cost based on hourly load dispatch is obtained for the variation in load demand using HS algorithm. By comparing HS to the pre-used algorithms in reference [12, 13] it can be observed from the Table III that the optimization process provides a better solution for a DED problem.

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