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Harris Hawks Optimization for Solving Optimum Load Dispatch Problem in Power System

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***Abstract*-Optimum load dispatch problem (OLDP) is regular work in operative scheduling that needs to be optimized, in the power system. Here in the paper the problem on optimum load dispatch technique for Harris hawk optimization is effectually and consistently presented. The result indicates OLDP for various test system examining transmission losses and the valve point loading effect. The concluding results gained using HHO are compared with other algorithms and found to be encouraging.**

Keywords— Optimum load dispatch; HHO , transmission losses & valve point effects

I. INTRODUCTION

Optimum load dispatch problem (OLDP) is one of the main consequential affair of the power system, which is intent for the output power for each constant which generates electricity unit in an effort to decrease the cost of operation and simultaneously limits the matching power operation and load demand usually to satisfy system constraints the power system operation is grounded on reducing the cost of operation. This problem is periodically made easier by establishing the premises like even and exterior cost curve of generating units, which consequence quadratic cost functions for a generator. Literally, OLDP's intentive function has nondiffusiable points by reason of the valve point effect ascribed to that cost curves are non–linear. Consequently in objective function, unsmooth cost function has to be involved. Intend conventional technique to solve OLDP contain the linear programming technique, incline technique, lambda repetition method and Newton's technique [1].

Long ago, numerous higher level approaches have been used to solve economic load dispatch such as Genetic algorithm [2,3], Tabu search [4],Evolutionary programming (EP) [5], Differential evolution [6] , particle swarm optimization (PSO) [7-10],gravitational search algorithm(GSA) [11], optimization on biogeography[12],Seeker optimization algorithm [13],Firefly algorithm [14],Simulated annealing (SA)[15],Harmony search[16,17],Shuffled frog leaping algorithm(SFLA) [18],Hybrid genetic algorithm(HGA) [19],Binary bat algorithm[20], Ant lion optimization[22], & multi verse optimization[23]etc.

Ali Asghar Heidariet.al. [21], suggest a new discover algorithm HHO inspired by chasing way of Harris hawks. In this report transmission losses for 3 and 6 generating unit systems solved economic load dispatch problem and HHO for 40 unit system solved the valve point effect. This section condenses the key steps to interpret the optimum load dispatch problem in HHO literature stated that the result acquired with the HHO algorithm was assessed and estimated with other methods.

PROBLEM PHRASING

For optimum load dispatch the objective function to be decreased, is given by:

$$F(P_g) = \sum_{i=1}^{n}(a_i P_{gi}^2 + b_i P_{gi} + c_i) \quad (1)$$

And after including the valve point loading effects the equation (1) is modified as below:

$$F(P_g) = \sum_{i=1}^{n}(a_i P_i^2 + b_i P_i + c_i) + \left|d_i \times \sin\{e_i \times (P_{gi}^{min} - P_{gi})\}\right|$$

Where fuel-cost coefficient's of the i[th] unit are a_i, b_i, and c_i, and d_i & e_i are with the valve-point effects [5].

The total fuel cost has to be decreased with the following restraints:

1) Power balance restraint

The power generation (P_{gi}) should be equal to the sum of power demand (P_d) and power loss (P_l).

$$\sum_{i=1}^{n} P_{gi} - P_d - P_l \quad (2)$$

The power loss P_l intended as:

$$P_l = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00} \quad (3)$$

2) Generator limit restraint

The particular lower operating limits P_{gi}^{min} and upper operating limits P_{gi}^{max} are controlled each generator's real power generation.

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \quad i=1,2,\ldots,ng \quad (4)$$

II. HARRIS HAWK OPTIMIZATION (HHO)

This section condenses the key steps to interpret the optimum load dispatch problem in Harris Hawk optimization (HHO). “Ali Asghar Heidariet” initiated the HHO. The Hunting activities of the Harris Hawks stimulated this algorithm. This predator demonstrates developed pioneering group pursuing ability in marking, enclosing, chasing ultimately assaulting the impending victim the Hawks in frequently will do a “leaping” movement right through the goal location and they reunite and how more than a few times to eagerly look for the sanctuary animal, that is mostly a rabbit. “Surprise pounce” is the major approach of Harris Hawks to imprison a victim that is also considered as “Seven Skill” technique.

With this prudent plan various agitators attempt to willingly assault from various directions and concurrently join to identify the escaped rabbit outside of the curve. In few seconds by imprisoning the surprising victim the assault may swiftly be finished but erratically concerning the escaping capabilities and action of the victim, many short –length speedy dives close to the victim throughout various minutes, may contain in the in the Seven kills..

i. *Exploration phase*

Harris’ hawks mainly based upon two techniques roost randomly on some location and hang around to identify a victim. If we take a fair possibility “q” for every roosting policy. They roost according to other family member’s and rabbit’s position. That is shown in equation (5) for q < 0.5, or roost on fluky lanky trees, that shown in equation (5) for q ≥0.5 condition.

$$X(t+1) = \begin{bmatrix} X_{rand}(t) - r_1|X_{rand}(t) - 2r_2X(t)| & q \geq 0.5 \\ X_{rabbit}(t) - X_m(t) - r_3\big(LB + r_4(UB - LB)\big) & q \leq 0.5 \end{bmatrix} \tag{5}$$

Where in the next repetition t, X (t + 1) is upcoming repetition position sector of hawks. Rabbit’s position is X_rabbit (t), recent various quantity of hawk’s is X (t), r1, r2, r3, r4, and q were fluky numbers in (0, 1), which are updated repitedly, Lower and Upper bounds are shown as LB and UB of various variables bounds, from the recent population X_random (t) is arbitrarily chosen hawk, and X_m (t) is the hawk’s average position’s current position.

ii. *Transformation from exploration to exploitation*

Power of the sufferer diminishes unusually during escaping actions. Energy of the sufferer is imitated as shown in equation no. (6)

E=2E0 (1-t/T) (6)

Here E is victim evading energy, T denoted the repetition’s extreme number, and E0 is the preliminary position of power. E0 at every repetition usually converts in HHO, at every repetition in the interim (-1, 1). E0 decreases from 0 to -1, rabbit is actually waning, that means strength of rabbit is increasing if the value of E0 expands from 0 to 1. In repetition Zestful escaping power E has a declining tendency. When |E| ≥1exploration occur, where |E| <1exploitation occur.

iii. *Exploitation phase*

During this stage, Harris’ hawks carry out astonishment dive (seven kills) by attacking the proposed sufferer identified in the previous phase. Just as the busting manners of the sufferer and the pursuing tactics of Harris Hawks, there are four probable strategies to show the pounce stage in the HHO.

E parameters employed to allow HHO to toggle between soft and hard besiege procedure, to explore this approach. Considerably, when |E| ≥0.5, the soft besiege occurs, and when |E| <0.5, the hard besiege take place.

a) *Soft besiege*

Rabbit still has sufficient vigor When r ≥0.5 and |E| ≥0.5, by some arbitrary deceptive jumps rabbit has an attempt to flee but lastly it cannot., Harris hawks enclose easily throughout these attempts to make more worn out the rabbit then carry out the surprise pounce. Rules shown following by this behavior

$$X(t+1) = \Delta X(t) - E\,|J X_{rabbit}(t) - X(t)| \tag{7}$$

$$\Delta X(t) = X_{rabbit}(t) - X(t) \tag{8}$$

Where ΔX (t) show the dissimilarity between the current position in iteration t, and vector of the rabbit, r_5 is an arbitrary number in (0, 1), and $J = 2(1 - r_5)$ shows the unsystematic dive power of rabbit all through the busting process. J alters usually in every repetition to replicate the motion character of rabbit.

b) *Hard besiege*

The sufferer is so worn out and it has a small escaping power when r ≥0.5 and |E| <0.5, then, the Harris hawks barely enclose the proposed victim to lastly carry out the astonishment dive. Additionally, the recent using eq. (9) updated in this situation.

$$X(t+1) = X_{rabbit}(t) - E\,|\Delta X(t)| \tag{9}$$

c) *Soft besiege with progressive rapid dives*

The rabbit has sufficient power to effectively escape When still |E| ≥0.5 but r<0.5 and still previously the astonishment dive a soft besiege is created. This process is cleverer than pretending case.

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In the HHO algorithm the levy flight (LF) concept is implemented. To precisely replicate the escaping patterns of the victim and the leap frog movement.

From the rule in the equation (10) it is believed that the Hawks can decide their subsequent moves to perform a soft besiege.

$Y = X_{rabbit}(t) - E\,|J\,X_{rabbit}(t) - X(t)|$ (10)

They evaluate the probable outcome of preceding jump to perceive that whether it be good or not. They also begin to carry out uneven, abrupt, and brisk dives if it was not rational, when approaching the rabbit. It is thought that LF-based patterns used by following rule:

$Z = Y + S \times LF(D)$ (11)

Levy flight function is LF and S is an arbitrary size 1 × D and D is the dimension of problem.

Eq. (10) can perform the Locations of hawks in the soft besiege phase.

$X(t+1) = \{Y \text{ if } F(Y) < F(X(t))$
$Z \text{ if } F(Z) < F(X(t))\}$ (12)

d) Hard besiege with progressive rapid dives

The rabbit has not adequate power to get away and hard besiege is done ahead of the astonishment dive to seize and kill the sufferer. When |E| <0.5 and r <0.5, the circumstances of victim side are alike the soft besiege, but at the time, the busting sufferer to minimize the average distance position of hawks. Accordingly, hard besiege condition shown in the following result:

$X(t+1) = \{Y \text{ if } F(Y) < F(X(t));\ Z \text{ if } F(Z) < F(X(t))\}$ (13)

Where eq.(14) and (15) obtain Y and Z using new rules.

$Y = X_{rabbit}(t) - E\,|J\,X_{rabbit}(t) - X_m(t)|$ (14)

$Z = Y + S \times LF(D)$ (15)

III. RESULTS& DISCUSSIONS

1) Study system I: Three generating units

The loss coefficient matrix B_{mn} data and input data of study system I has taken from reference [14] with the help of HHO technique solved the study system I and compare with the other techniques.

Table 1.1: Results of study system I with the help of HHO technique

Sr.no.	Power Demand (MW)	P1(MW)	P2(MW)	P3(MW)	P_{Loss} (MW)	Fuel Cost (Rs/hr)
1	500	105.8	212.62	193.5	11.91568	25465.47042
2	700	154.51	289.36	279.88	23.7679	35424.44203

Table 1.2: Comparison of study system I results to other techniques.

Sr.no.	Power demand (MW)	Fuel Cost (Rs/hr)		
		Lambda Iteration Method [14]	Fire Fly algorithm [14]	HHO
1	500	25495.2	25465.5	25465.469
2	700	35466.3	35424.4	35424.44203

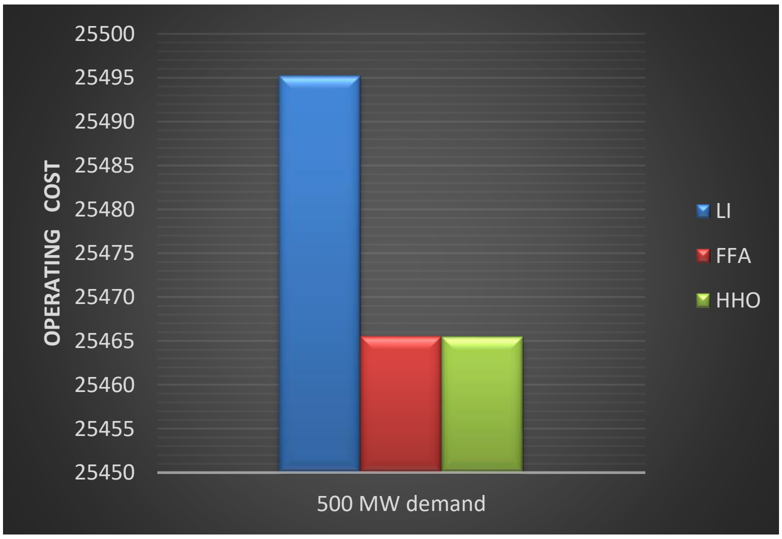

Figure 1: Comparison of fuel cost with other techniques

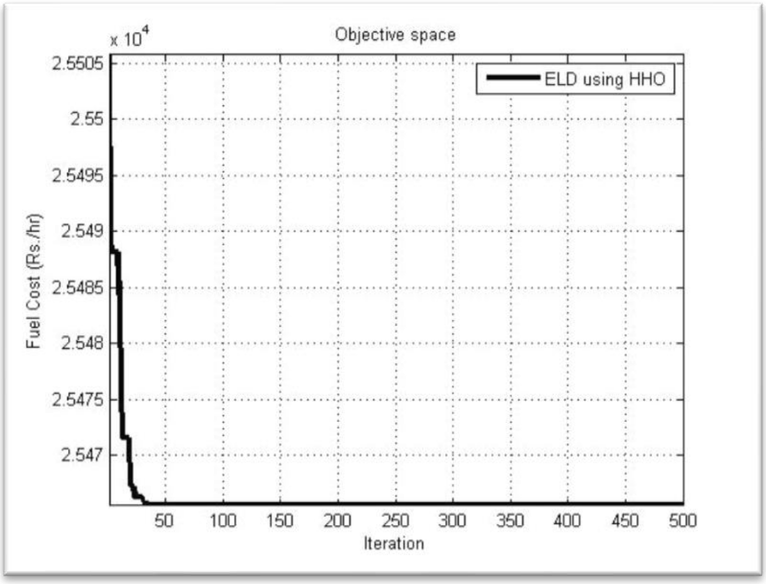

Figure 2: Convergence curve for 3 generators with 500 MW demand

Study system II: Six generating units

The loss coefficient matrix B_{mn} data and input data of study system II has taken from reference [14] with the help of HHO technique solved the study system II and compare with the other techniques

Table 1.3: Results of study system II with the help of HHO technique

Sr.no.	Power Demand (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	P_{Loss} (MW)	Fuel Cost (Rs/hr)
1	700	28.29	10.00	119.23	118.51	230.66	212.72	19.428	36912.14
2	900	36.64	21.13	163.65	153.09	284.08	273.40	31.9911	47045.176

Table 1.4: Comparison of study system II results to other techniques.

Sr.No.	power demand (MW)	Fuel Cost		
		Lambda Iteration Method [14]	FireFly Algorithm [14]	HHO
1	700	36946.4	36912.2	36912.14
2	900	47118.2	47045.3	47045.176

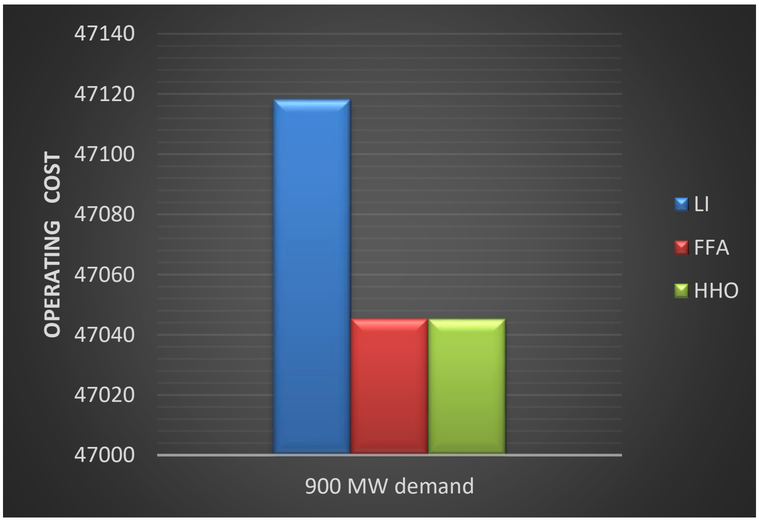

Figure 3: Comparison of fuel cost with other techniques for900 MW demand

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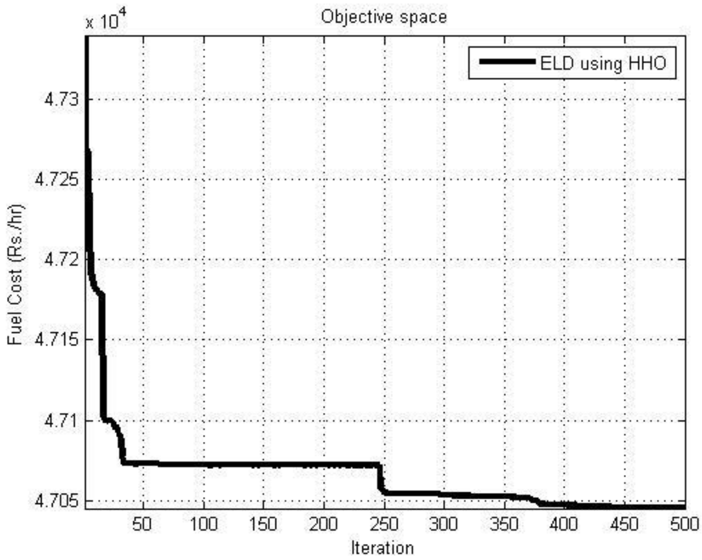

Figure 4: Convergence curve for 6 generators with 900MW demand

2) *Study system III: Forty generating units*

The 40 generating units' data is adopted from [5]. In this case valve point effect has been considered while solving optimum load dispatch using HHO algorithm. The results obtained have been depicted below in tabular form and compared with other algorithms.

Table 1.5: OLDP using HHO for study system III with 10,500 MW load demand

Gen	Power Output	Gen	Power Output	Gen	Power Output	Gen	Power Output
Pg1	113.998	Pg11	98.3407	Pg21	527.208	Pg31	190
Pg2	113.660	Pg12	103.580	Pg22	523.685	Pg32	190
Pg3	100.205	Pg13	125.020	Pg23	523.692	Pg33	189.989
Pg4	180.880	Pg14	394.282	Pg24	524.641	Pg34	173.497
Pg5	88.490	Pg15	394.329	Pg25	523.454	Pg35	200
Pg6	139.994	Pg16	394.283	Pg26	523.268	Pg36	199.975
Pg7	300	Pg17	489.677	Pg27	10.681	Pg37	97.072
Pg8	284.970	Pg18	489.568	Pg28	10.252	Pg38	109.987
Pg9	289.585	Pg19	512.127	Pg29	10.544	Pg39	109.843
Pg10	130.113	Pg20	511.450	Pg30	96.373	Pg40	511.271
Total power generation (MW)		10500		**Minimum Cost (Rs)**		121731.6224	

Table 1.6: comparison of OLDP results for study system III with other algorithms in literature.

Method	**Minimum Cost ($/ h)**	**Average Cost ($/ h)**	**Maximum Cost ($/ h)**
HGPSO [52]	124797.13	126855.70	NA
SPSO [52]	124350.40	126074.40	NA
PSO [18]	123930.45	124154.49	NA
CEP [47]	123488.29	124793.48	126902.89
HGAPSO [52]	122780.00	124575.70	NA
FEP [47]	122679.71	124119.37	127245.59
MFEP [47]	122647.57	123489.74	124356.47
IFEP [47]	122624.35	123382.00	125740.63
TM [53]	122477.78	123078.21	124693.81
EP-SQP [18]	122323.97	122379.63	NA
MPSO [54]	122252.26	NA	NA
ESO [55]	122122.16	122524.07	123143.07
HPSOM [52]	122112.40	124350.87	NA
PSO-SQP [18]	122094.67	122245.25	NA
GA_MU [57]	122000.2837	NA	NA
Improved GA [56]	121915.93	122811.41	123334.00
HPSOWM [52]	121915.30	122844.40	NA
IGAMU [57]	121819.25	NA	NA
HDE [58]	121813.26	122705.66	NA
PSO [21]	121735.4736	122513.9175	123467.40
HHO	121731.6224	122310.253	122954.09

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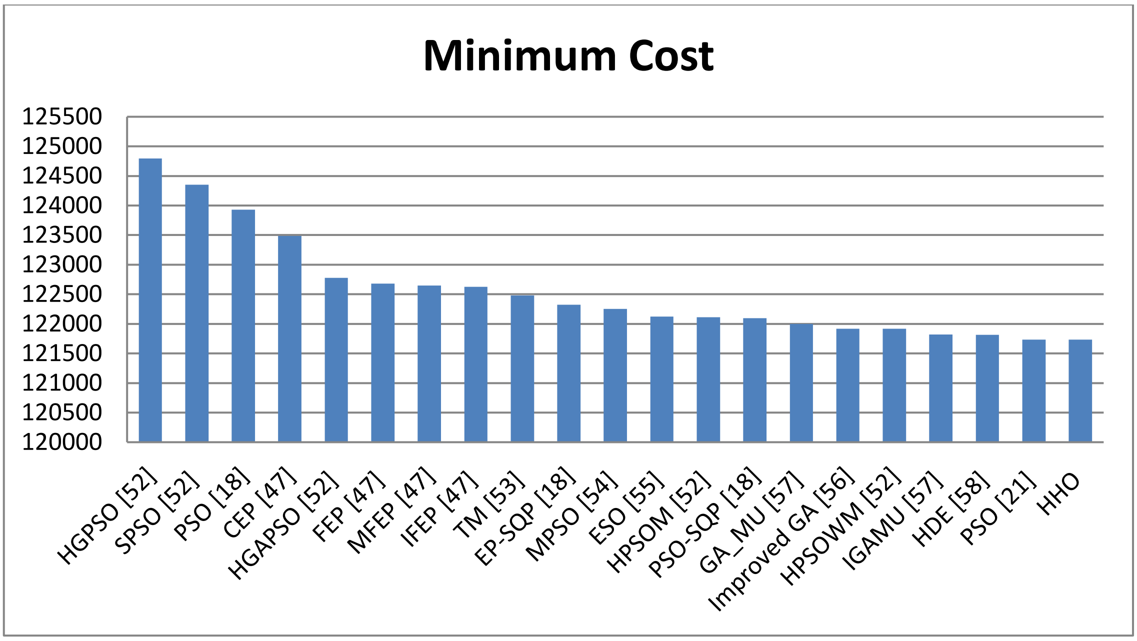

Figure 5: Comparison of results for 40-Unit system

IV. CONCLUSION

HHO is latest higher level technique. In this report OLDP is solved with transmission losses and valve point effects using HHO for different test cases. In power system to solve optimum load dispatch the affect outcome unveil the potency of hardness of the HHO algorithm. The algorithm is used in MATLAB (R2009) Software. For solving optimum load dispatch problem the differentiation of the results with other methods unveil the accomplishment of HHO algorithm.

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