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Dispatching Economically Restricted Loads Using a Biogeography-Based Optimization Algorithm and an Improved Harmony Search Algorithm

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Abstract
HSA, IHS, and BBO algorithms are compared in this work for handling restricted economic load dispatch issues in a power system with a limited number of available resources. New solution vectors are generated using the IHS algorithm, which makes use of numerous harmony memory consideration rates and dynamic pitch adjustment rates. They were tested in a test system with twenty producing units with ramp rate restrictions and valve point loading constraints, and the algorithms worked well. IHS approach outperforms both Harmony search and Biogeography-based optimization algorithm in terms of total fuel cost and convergence characteristics, as shown by the simulation results.

Introduction
Customers' requests for electrical energy must be met promptly and efficiently, as mandated by national legislation, by the vast majority of the world's electric power companies. Despite meeting the country's power needs, the utility must also guarantee that the electricity is produced at the lowest possible cost. This means that the entire demand must be distributed among the generating units in a way that reduces the system's overall generation cost while still meeting the economic needs of the system. There are several ways to calculate how much power is created by each committed producing unit in order to keep overall costs down while still meeting demand for electricity.

Economic dispatch is one such method. "The operation of generating facilities to provide energy at the lowest cost to reliably supply customers, recognising any operational restrictions of generation and transmission infrastructure" might be termed as "economic dispatch". Allocating generating among committed units in order to meet limits and reduce energy consumption in terms of dollars per hour is an essential optimization job in power system operation. Figure 1 depicts a simple heat rate curve, which depicts the input-output relationship of a thermal unit (a). When the heat rate curve is converted from Btu/h to $/h, the fuel cost curve depicted in Fig. 1 may be seen (b)

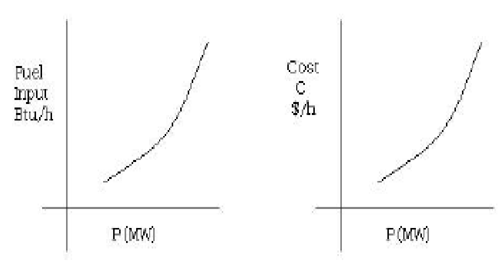

Fig. 1(a) Power Vs Fuel input Fig. 1(b) Power Vs Cost

A variety of derivatives-based approaches, including as lambda iteration, gradient technique, Lagrangian Multiplier method, Dynamic Programming method, were previously used to tackle ELD issues. Because to valve point effect, ramp rate limits, and so on, contemporary generators' input-output characteristics are non-linear. Genetic algorithm (GA), particle swarm optimization (PSO), and artificial bee colony (ABC) optimization approaches have recently been used to tackle the ELD issue with non-smooth cost functions, and have proved effective. The Harmony search algorithm is one of these more contemporary methods.

As in improvised music, the goal of the "harmony search" (HS) algorithm is to find the best possible harmony by analysing the pitches of the individual artists involved. The process of musical improvisation resembles that of optimal design, which is concerned with arriving at the best possible solution. Harmony is defined by the pitch of each musical instrument, exactly like a collection of variables. The Upgraded Harmony Search Algorithm (IHSA) is an improved version of HS. This article discusses the IHS method for solving the ELD issue with the addition of Ramp Rate limitations.

Problem Formulation

The main objective of economic load dispatch *problem is to minimize*

$$\min f = \sum_{i=1}^{N} F_i(P_i) \qquad (1)$$

Where $F_i$is the total fuel cost for the generator unity i (in $/h), which is defined by equation:

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i (2) \qquad (2)$$

Where a_i,$_i$and $c_i$are cost coefficients of generator i. Two constraints are consideredin thisproblem, i.e., thegenerationcapacityofeach generatorandthepowerbalanceoftheentirepowersystem.

Constraint1:Thisconstraintisaninequalityconstraintforeachgenerator.Fornormalsystemoperations,realpower output of each generator is within its lower and upper bounds and is known as generation capacity constraintgivenby

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \qquad (3)$$

Constraint 2:This constraintis an equality constraint. Inwhich the equilibrium ismetwhen the total powergenerationmustequals thetotaldemand $P_D$andtherealpowerlossin transmission lines$P$. Thisisknown aspower balance constraint canbeexpressedas given in

$$\sum_{i=1}^{N} P_G = P_D + P_L \qquad (4)$$

Rampratelimitconstraint: The power generated, Pi0 by the ith generator in certain interval may not exceed thatofpreviousintervalPi0bymorethanacertainamountURi,theup-rampratelimitandneithermayitbelessthanthat of the previous interval by more than some amount DRithe down ramprate limit of the generator .These giverisetothefollowingconstraints.

As generation increases

$$P_i - P_{i0} \leq UR_i$$

As generation decreases

$$P_{i0} - P_i \leq DR_i$$

and

$$max(P_i^{min}, P_{i0} - DR_i) \leq P_i \leq \min(P_i^{max}, P_{i0} + UR_i) \quad (5)$$

Valvepointloadingconstraint:

Thevalve-pointloadingistakeninconsiderationbyaddingasinecomponenttothecostofthegeneratingunits.Typically,thefuelcostfunctionof thegenerating unitswithvalve-pointloadingsisrepresentedinFig.2.

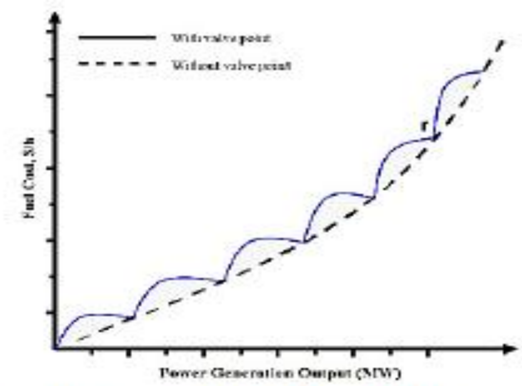

Fig. 2 Power generation output Vs Fuel cost

HarmonySearchAlgorithm

An algorithm developed by Geem that mimics the improvisation of musicians is known as the harmony search (HS) algorithm. A musician's improvisations are equivalent to the local and global search strategies used in optimization techniques, and the harmony they create may be compared to an optimization solution vector. Instead of a gradient search, the HS method employs a stochastic random search. Harmony memory and pitch adjustment rate are used to discover the solution vector in the search space using this approach. In order to obtain the optimal value for the objective function, the HS algorithm employs the notion of how aesthetic assessment helps to reach the perfect condition of harmony. The HS method has a few parameters and is straightforward to apply conceptually and practically. A number of optimization issues have been solved using this technique. The HS algorithm's optimization approach is as follows:

- Initializetheoptimizationproblemandalgorithmparameters.
- Initializetheharmonymemory.
- ImprovisationofaNewHarmonymemory.
- Updatetheharmony memory.
- Checkforstoppingcriteria.Otherwise,repeatstep3to4

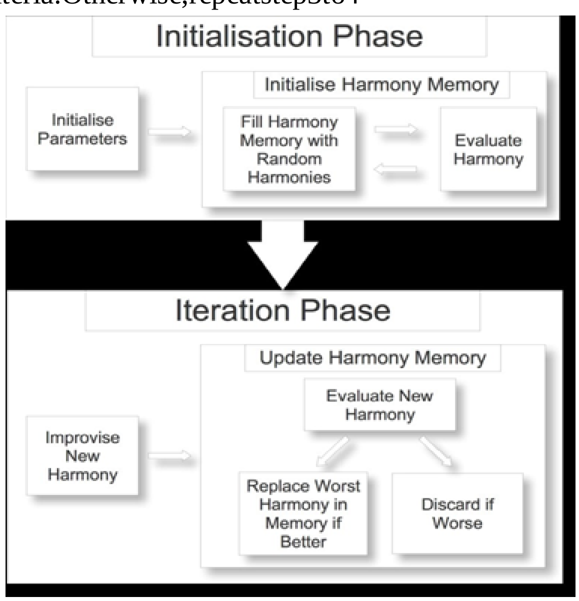

Fig. 3: Block Diagram of Harmony search Algorithm

ImplementationoftheProposedApproach

- TheproposedapproachtosolveELDproblemisdescribedinthefollowingsteps.
- Inputthesystemparameters,minimumandmaximumlimitsofcontrolvariables.
- ChoosetheharmonymemorysizeHMS,pitchadjustingratePAR,bandwidthBWandthemaximumnumb erofimprovisationsNI.
- InitializetheharmonymemoryHMasexplainedinthesectionIII-B.Whileinitializing,allthecontrolvariablesarerandomlygeneratedwithintheirlimits.

Starttheimprovisation.

- ForeachsolutionvectorinHM,evaluatetheobjectivefunctions.
- ImprovisetheNewHarmonymemory asexplainedinthesectionIII-C.

Table 1 : Comparison of fuel cost coefficients for different generators

No.of Generators	P_{min} (MW)	P_{max} (MW)	A ($/MWhr)	B ($/MWhr)	C ($/MWhr)
1	50.0	300	95	6.8000	0.0070
2	50.0	450	30	4.0000	0.0055
3	50.0	450	45	4.0000	0.0055
4	0.0	100	10	0.8500	0.0025
5	50.0	300	20	4.6000	0.0060
6	50.0	450	90	4.0000	0.0055
7	50.0	200	42	4.7000	0.0065
8	50.0	500	46	5.0000	0.0075
9	0.0	600	55	6.0000	0.0085
10	0.0	100	58	0.5000	0.0020
11	50.0	150	65	1.6000	0.0045
12	0.0	50	78	0.8500	0.0025
13	50.0	300	75	1.8000	0.0050
14	0.0	150	85	1.6000	0.0045
15	0.0	500	80	4.7000	0.0065
16	50.0	150	90	1.4000	0.0045
17	0.0	100	10	0.8500	0.0025
18	50.0	300	25	1.6000	0.0045
19	100.0	600	90	5.5000	0.0080
20	120.0	500	18	6.7000	0.0020

- Performthenon-dominatedsortingandrankingonthecombinedexistingandNewHarmonymemory
- ChoosethebestharmonymemoryfromthecombinedsolutionvectorsasgiveninthesectionIII-Dforthenext improvisation.
- Checkforstoppingconditions.Ifthenumberofimprovisationshasbeenreachedstopthealgorithm.Other wise,goto step5.

Table 2 : Comparison of BBO, HS, IHS with ramp rate limit

LOAD DEMAND(MW)	BBO TOTAL COST($/hr)	HSA TOTAL COST($/hr)	IHSA TOTAL COST($/hr)
925	1232.90	1020.56	846.324
1000	1438.00	1120.12	989.94
1500	2487.52	2332.41	2234.32
2000	4257.37	4167.8	3979.26
2500	6477.52	6421.93	6224.65

BiogeographyBasedOptimisationAlgorithm

BBO, suggested by Dan Simon in 2008, is a stochastic optimization technique for solving multimodal optimizationproblems. It is based on the concept of biogeography, which deals with the distribution of species that depend ondifferent factorssuchasrainfall, diversityetc.Themain partsofBBOalgorithm includes Migration

ThealgorithmstepsofBBOareasfollows

Step1:InitializationoftheBBOparameters.
Step2:The initial position of SIV of each habitat shouldbe randomlyselectedwhile satisfying different equalityand inequality constraints of ELD problems. Several numbers of habitats depending upon the population size arebeinggenerated. Eachhabitatrepresents a potentialsolutionto thegiven problem.
Step3:CalculateeachHSIi.e.valueofobjectivefunctionforeachi-thhabitatofthepopulationsetnforgiven emigrationrateμs,immigrationrateλsandspeciesS.
Step4:BasedontheHSIvaluessomeelitehabitatsareidentified.
Step5:Eachnon-elitehabitatismodifiedbyperformingprobabilisticallyimmigration andemigrationoperation.Step6:Speciescountprobabilityofeachhabitatisupdatedusingequation11.Mutationoperationisperformedonthenon-elite habitatand HSIvalue ofeachnewhabitatis computed.
Step7:Feasibility ofaproblemsolutionisverifiedi.e.eachSIVshouldsatisfy equalityandinequality constraints.
Step8:Gotostep3 forthenextiteration.
Step9:Stopiterationsafterapredefinednumberofiterations.

SimulationResults

Using the 20-generator test system, the fuel cost coefficients and generation limitations for each generator are shown in Table 1. Harmony Search algorithm (HSA), IHSA and Biogeography based optimization algorithm (BBO) are compared in a simulation and the results are displayed in Table 2. With regard to valve point loading, the findings are shown in Table 3.

Table 3 : Comparison of BBO, HSA, IHS with valve point loading

LOAD DEMAND(MW)	BBO TOTAL COST($/hr)	HS TOTAL COST($/hr)	IHS TOTAL COST($/hr)
925	872.425	838.14	687.79
1000	1036.84	1016.54	976.98
1500	2266.82	2157.54	1004.87
2000	4016.83	3354.98	2900.889
2500	6266.83	5735	4089.13

RAMPRATECONSTRAINT:

Theconvergencecharacteristicsobtainedforallthethreealgorithmswiththeinclusionoframpratelimitcostraintis showninFig.4.Thecomparison offuelcostwith ramprateis shown inFig.5.

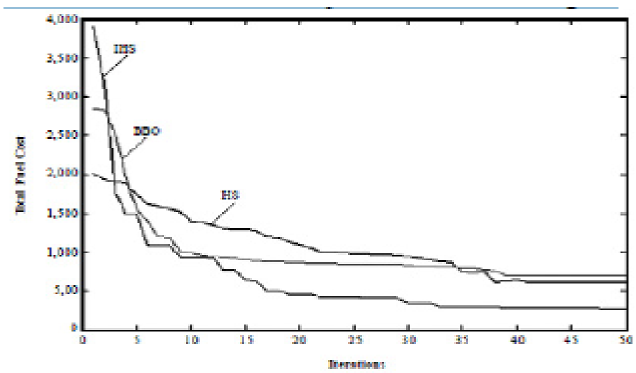

Fig. 4 Convergent characteristic of all algorithms

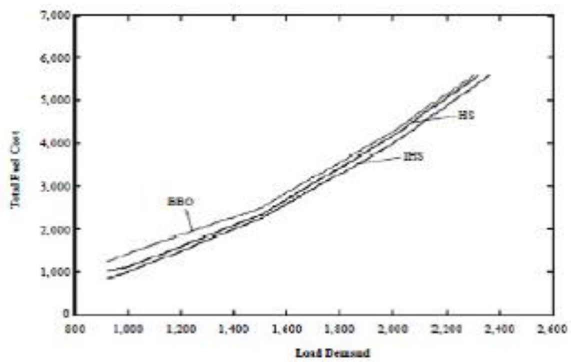

Fig 5 Comparison of Fuel Cost Solution

VALVEPOINTLOADINGCONSTRAINT:

The convergence characteristics obtained for all the three algorithms with the inclusion of valve point loadingconstraint is shown in Fig. 6. The comparison of fuel cost with valve point loading is shown in Fig. 7.

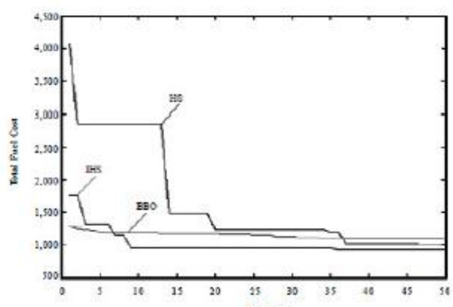

Fig. 6 Convergence Characteristics Between IHS, HS, BBO with Valve point loading

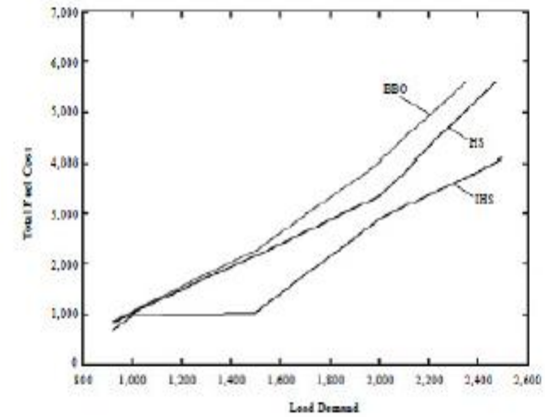

Fig. 7 Comparison of fuel cost from the table with valve point loading

Conclusion

It is possible to solve the economic load dispatch issue in the power system by applying the IMPROVED HARMONY SEARCH ALGORITHM (IHS), the HARMONY SEARCH ALGORITHM (HSA), and the BIOGEOGRAPHY BASED OPTIMIZATION ALGORITHM (BBO). The simulation results show that the IHS algorithm outperforms both the HS and BBO algorithms in terms of performance and overall fuel cost. HS algorithm may be well-known, but it is considered innovative and imaginative when it is compared to BBO and IHS under restrictions of ram prate and valve point loading in order to save fuel costs.

Because of these two factors, the Improved Harmony Search algorithm is superior than previous algorithms.

- ✓ When compared to alternative options, the total fuel cost is the lowest.
- ✓ When compared to others, the reaction time of convergence characteristics is very rapid.

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