Solving Economic Load Dispatch Using JAYA Optimization Algorithm

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Abstract
Economic load dispatch (ELD) problem is one of the crucial issues in power system operational control. The ELD solution determines the best allocation of demand amongst the committed generating units subject to fulfillment of power balance and capacity constraints, such that the total system cost is kept as reduced.

In this study, JAYA optimization algorithm is aspired to solve the ELD solutions. This proposed technique is based on the concept that the solution obtained for a given problem progress towards the best solution and should avoid the worst solution. In order to validate the proposed algorithm, it is implemented in three and fifteen generators systems respectively. The simulation results demonstrate that the aspired algorithms produce more optimal result in both cases when compared with other optimization algorithms.

Keywords: Economic Load Dispatch, Optimum Power Allocation, Power Balance and Capacity Constraints.

Introduction

The process of scheduling the generation to reduce the fuel cost of the system is named as economic load dispatch. ELD is an essential daily optimization task in the operation of a power system. Various mathematical programming methods and optimization techniques have been implemented to ELD. The paper[1] propose the hybrid algorithm such as PSO and GSA technique to solve ELD with generator constraints for six and fifteen generator systems. The paper[3] proposed about a newly proposed Novel TANAN's algorithm for solving convex economic load dispatch considering transmission losses for 3 unit system.

The paper[5] proposes the PSO algorithm based on constriction factor is used to solve the economic load dispatch. The paper[6,7] proposed solution for the optimal power flow for six and thirteen unit system. The paper[4] propose the improved Tabu search for heavily constrained optimized problem. The paper[9] describes optimal power flow with limited generator constrains with transmission losses for six unit system.

In this paper, JAYA optimization algorithm is used for solving economic load dispatch. It is a newly developed algorithm for solving constrained and unconstrained optimization problem. Section one demonstrates the Economic Load Dispatch concept. Section 2 demonstrates the JAYA optimization algorithm and flowchart. Section 3 shows the test case systems and Section 4 implies the validation of results.

Problem Formulation for Economic Load Dispatch: The ELD solution is described as an objective function to minimize the total fuel cost while satisfying different constraints, the problem formulation described.

$$\text{Min } F=\Sigma_{i=1}^{n} F_i(P_i) \tag{1}$$

where n is the total number of generators in power systems, $F_i(P_i)$ is the cost function of i^{th} generator with output P_i. Similarly, the cost function can expressed as a quadratic polynomial equation:

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \tag{2}$$

where a_i, b_i, c_i are the cost coefficients of i^{th} generator, which are constants.

Constrained Functions

Power Losses: The total power generated by considered units must equal to the summation of the required power demand and the transmission loss, which can be formulated below:

$$\sum_{i=1}^{n} P_i = P_{demand} + P_{loss} \tag{3}$$

where P_{demand} and P_{loss} is the value of the demanded power and the whole power loss in the system respectively. P_{loss} is calculated by Kron's formula:

$$P_{loss}=\sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{i0} P_i + B_{00} \tag{4}$$

where B_{ij}, B_{i0}, B_{00} are the loss coefficients that generally can be assumed to be constants under normal operating condition.

Generating Capacity: The real output P_i generated by an available unit must be ranged between its minimum limit and maximum limit:

$$P_i^{min} \le P_i \le P_i^{max} \tag{5}$$

JAYA Optimization Algorithm: The word JAYA is derived from the Sanskrit means victory. The JAYA optimization algorithm is an advanced optimization technique developed for solving constrained and unconstrained optimization equations. It does not require any hyper parameters except for two common parameters such as population size (N_{pop}) and the number of iteration (N_{iter}). The multi-population (Mp) based JAYA optimization algorithm is proposed in this paper. Its implementation moves towards good solution and avoids the worst solution. In this method, the total population is divided into sub-populations to control the exploration and exploitation rates. The basic JAYA algorithm has only one phase according to the above mentioned concept. Figure 1 illustrates the flowchart of the JAYA algorithm.

Algorithm

Step 1: Required parameters of JAYA are initialized in this step.
Step 2: A set of initial solution are randomly generated.
Step 3: Apply the constraints by using equations (4),(5),(6).
Step 4: Calculate the cost function by using equations F(x)
Step 5: Determine the best value and worst value among the entire value
Step 6: Generate the new output solution by equation
Step 7: Apply the constraints by using equations (4), (5), (6).
Step 8: Calculate the new cost function value by equation F(x)
Step 9: Return to step 5 otherwise stop the procedure.

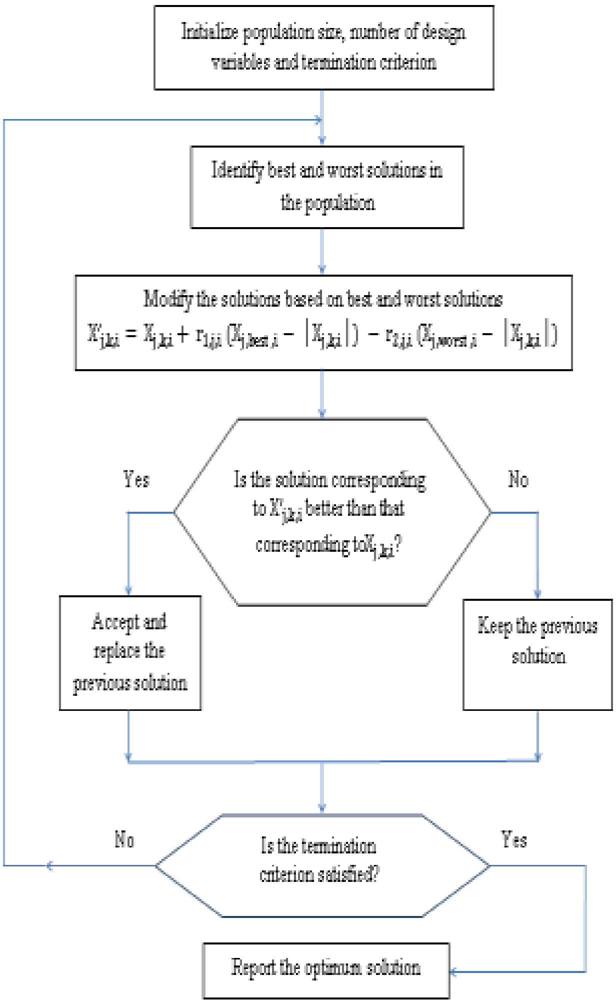

Figure 1: Flow chart of JAYA Optimization Algorithm

Case Study

Case 1: In order to verify the effectiveness of the proposed three-unit power system was tested. The test system was composed of 3 generating units and the input data of the three generator system are as given in the Table 1. The total demand for the system is 850MW.

Table 1
Data for Test Case (3-Unit System)

Unit	P^{min} (MW)	P^{max} (MW)	a ($/MW /hr)	b ($/MW /hr)	C ($/MW/hr)
1	100	600	561	7.92	0.0001562
2	100	400	310	7.85	0.001940
3	50	200	78	7.97	0.004820

B-Coefficient matrix:

B = [0.000075 0.000005 0.0000075
0.000005 0.009990 0.0000100
0.0000075 0.000010 0.000045]

Case 2: In order to verify the feasibility of the proposed method, the fifteen-unit system was tested. The test system composed of 15 generating units and the input data of the fifteen generator system are as given in the table 2.

Table 2
Data for Test Case (15-Unit System)

Unit	P^{min} (MW)	P^{max} (MW)	a ($/MW/hr)	b ($/MW/ hr)	c ($/MW /hr)
1	455	150	0.00029	10.1	671
2	455	150	0.000183	10.2	574
3	130	20	0.001126	8.8	374
4	130	20	0.001126	8.8	374
5	470	150	0.000205	10.4	461
6	460	135	0.000301	10.4	630
7	465	135	0.000364	9.8	448
8	300	60	0.000338	11.2	227
9	162	25	0.000807	11.1	173
10	160	25	0.001203	10.7	175
11	80	20	0.003586	10.2	186
12	803	20	0.005513	9.9	130
13	85	25	0.000371	13.1	225
14	55	15	0.0001929	12.1	309
15	55	15	0.00447	12.4	323

$$B_{ij} = \begin{bmatrix} 0.0014 & 0.0012 & 0.0007 & -0.0001 & -0.0003 & -0.0001 & -0.0001 & -0.0001 & -0.0003 & 0.0005 & -0.0003 & -0.0002 & 0.0004 & 0.0003 & -0.0001 \\ 0.0012 & 0.0015 & 0.0013 & 0.0000 & -0.0005 & -0.0002 & 0.0000 & 0.0001 & -0.0002 & -0.0004 & -0.0004 & -0.0000 & 0.0004 & 0.0010 & -0.0002 \\ 0.0007 & 0.0013 & 0.0076 & -0.0001 & -0.0013 & -0.0009 & -0.0001 & 0.0000 & -0.0008 & -0.0012 & -0.0017 & -0.0000 & -0.0026 & 0.0111 & -0.0028 \\ -0.0001 & 0.0000 & -0.0001 & 0.0034 & -0.0007 & -0.0004 & 0.0011 & 0.0050 & 0.0029 & 0.0032 & -0.0011 & -0.0000 & 0.0001 & 0.0001 & -0.0026 \\ -0.0003 & -0.0005 & -0.0013 & -0.0007 & 0.0090 & 0.0014 & -0.0003 & -0.0012 & -0.0010 & -0.0013 & 0.0007 & -0.0002 & -0.0002 & -0.0024 & -0.0003 \\ -0.0001 & -0.0002 & -0.0009 & -0.0004 & 0.0014 & 0.0016 & -0.0000 & -0.0006 & -0.0005 & -0.0008 & 0.0011 & -0.0001 & -0.0002 & -0.0017 & 0.0003 \\ -0.0001 & 0.0000 & -0.0001 & 0.0011 & -0.0003 & -0.0000 & 0.0015 & 0.0017 & 0.0015 & 0.0009 & -0.0005 & 0.0007 & -0.0000 & -0.0002 & -0.0008 \\ -0.0001 & 0.0001 & 0.0000 & 0.0050 & -0.0012 & -0.0006 & 0.0017 & 0.0168 & 0.0082 & 0.0079 & -0.0023 & -0.0036 & 0.0001 & 0.0005 & -0.0078 \\ -0.0003 & -0.0002 & -0.0008 & 0.0029 & -0.0010 & -0.0005 & 0.0015 & 0.0082 & 0.0129 & 0.0116 & -0.0021 & -0.0025 & 0.0007 & -0.0012 & -0.0072 \\ -0.0005 & -0.0004 & -0.0012 & 0.0032 & -0.0013 & -0.0008 & 0.0009 & 0.0079 & 0.0116 & 0.0200 & -0.0027 & -0.0034 & 0.0009 & -0.0011 & -0.0088 \\ -0.0003 & -0.0004 & -0.0017 & -0.0011 & 0.0007 & 0.0011 & -0.0005 & -0.0023 & -0.0021 & -0.0027 & 0.0140 & 0.0001 & 0.0004 & -0.0038 & 0.0168 \\ -0.0002 & -0.0000 & -0.0000 & -0.0000 & -0.0002 & -0.0001 & 0.0007 & -0.0036 & -0.0025 & -0.0034 & 0.0001 & 0.0054 & -0.0001 & -0.0004 & 0.0028 \\ 0.0004 & 0.0004 & -0.0026 & 0.0001 & -0.0002 & -0.0002 & -0.0000 & 0.0001 & 0.0007 & 0.0009 & 0.0004 & -0.0001 & 0.0103 & -0.0101 & 0.0028 \\ 0.0003 & 0.0010 & 0.0111 & 0.0001 & -0.0024 & -0.0017 & -0.0002 & 0.0005 & -0.0012 & -0.0011 & -0.0038 & -0.0004 & -0.0101 & 0.0578 & -0.0094 \\ -0.0001 & -0.0002 & -0.0028 & -0.0026 & -0.0003 & 0.0003 & -0.0008 & -0.0078 & -0.0072 & -0.0088 & 0.0168 & 0.0028 & 0.0028 & -0.0094 & 0.1283 \end{bmatrix}$$

$$B_{0i} = [-0.0001, -0.0002, 0.0028, -0.0001, 0.0001, -0.0003, -0.0002, -0.0002, 0.0006, 0.0039, -0.0017, -0.0000, -0.0032, 0.0067, -0.0064$$

$$B_{00} = 0.0055$$

Simulation and Results

The simulation result for the three generator units system is given in the Table 3. From the Table 3 it is revealed that the minimum cost is obtained as 8212.1($/hr) for without losses and 8276($/hr) for with losses. The results are compared with the PSO algorithm.

Table 3
Comparison of Simulation Results for JAYA Algorithm

Unit no	PSO without losses	JAYA without losses	PSO with losses	JAYA with losses
1	300.268	460.228	376.1	291.007
2	400	245.118	376.1	433.199
3	149.732	146.496	104	138.916
Total generation (MW)	850	850	856.314	863.123
Minimum cost ($/hr)	8234	8212.1	8257.9	8276.0

Without losses: The convergence characteristics of the cost function for without transmission losses for 3 units system is shown in figure 2.

With losses output: The convergence characteristics of cost function for with transmission losses for 3-unit system is show in figure 3.

Case: 2 (15-unit test system): The simulation result for the fifteen generator units system is given in the Table 4. From the Table 4 it is revealed that the minimum cost is obtained as 32554($/hr) for without losses and 32197($/hr) for with losses. The results are compared with the PSO algorithm.

Without Losses: The convergence characteristics of the cost function for without transmission losses for 15-unit system is shown in figure 4.

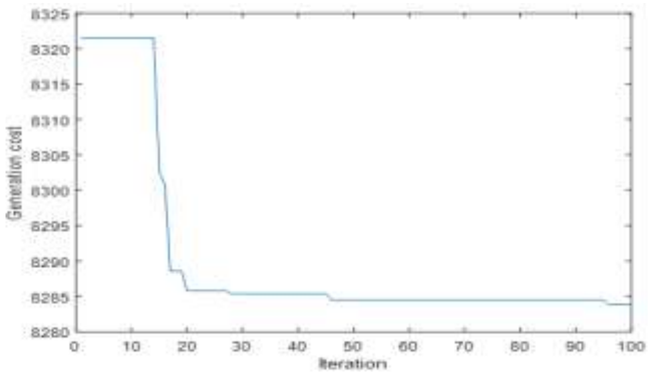

Figure 2: Fuel cost convergence characteristics of 3-unit system with losses

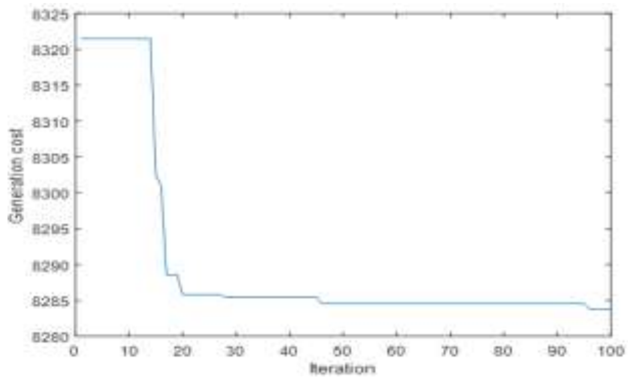

Figure 3: Fuel cost convergence characteristics of 3-unit system with losses

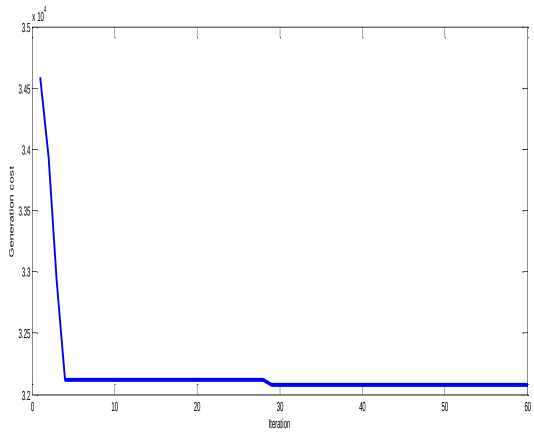

Figure 4: Fuel cost convergence characteristics of 15-unit system without losses

Table 4
Comparison of Simulation Results for JAY Algorithm

Unit	PSO Without Losses	JAYA Without Losses	PSO with Losses	JAYA with Losses
1	405.34	127.57	439.116	301.1
2	415.34	342.5	407.972	263.4
3	102.48	327.3	407.972	276.1
4	127.42	179.8	129.992	138.0
5	354.79	450	151.068	302.3
6	460	672	459.997	813
7	376.50	156.9	425.560	-373
8	64.30	564	98.5699	477
9	25.40	-102.7	113.493	120.9
10	136.72	715	101.114	193.6
11	40.75	162.3	33.9116	165.7
12	36.64	95.5	79.9583	276.0
13	31.14	-393.4	25.0042	-271.7
14	22.48	194.7	41.4140	319
15	30.65	158	36.6140	248
Total Generation (MW)	2630	2636.7	2662.43	2641
Cost ($/Hr)	32554	32078	32858	32197

With Losses: The convergence characteristics of cost function for with transmission losses for 15-unit system is shown in figure 5.

Conclusion

This paper represents a new technique for determine the economic load dispatch solution using JAYA optimization algorithm for three and fifteen-unit generator systems. The strong convergence characteristic of the proposed method is also ensured during in solving the economic load dispatch problem. Simulation on the three generators and fifteen generator systems demonstrate the feasibility and effectiveness of the proposed method in reducing the cost of the generation. The simulation output shows that improvements were made to solve the economic load dispatch problem effectively. At last, it has been demonstrated that the proposed system improves the convergence and performs better when compared with other algorithms.

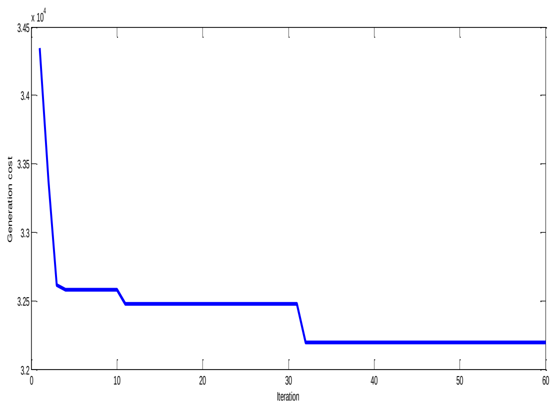

Figure 5: Fuel cost convergence characteristics of 15-unit system with losses

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