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Genetic Algorithm based Multiobjective Optimal Power Dispatch based on Ideal Distance Minimization

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***Abstract**: In this paper, the cost of generation and system transmission losses have been considered as objectives for optimization. The multiobjective optimal power dispatch (MOPD) problem is formulated using weighting method and a number of noninferior solutions are generated in 2D space by varying weights for IEEE 5, 14 and 30 bus systems – manually using GA technique, by using GA toolbox of MATLAB R2008b. Ideal Distance minimization method has been used to obtain the optimal power system operation (Target Point, best compromise solution). This method employs the concept of an 'Ideal Point' (IP) to scalarize the problems having multiple objectives and minimizes the Euclidean distance between IP and a set of noninferior solutions.*
***Keywords:** Multiobjective Optimal Power Dispatch, weighting method, 2D space, Genetic Algorithm (GA).*

I. Introduction

Economic load dispatch is most efficient, low cost and reliable operation of a power system by dispatching the available electricity generation resources to the load on the system. The primary objective of economic dispatch is to minimize the total fuel cost of generation while honoring the operational constraints of the available generation resources.

Multiobjective optimization (or programming), [1, 2, 3] also known as multi-criteria or multi-attribute optimization, is the

process of simultaneously optimizing two or more conflicting objectives subject to certain constraints.

In single objective optimization methods, the analyst can make only one suggestion. In case it is not acceptable to the management and the decision making process gets stuck up. This is not the case with multiobjective approach as analyst has a number of alterative suggestion, one of which the management has to choose one.

The way out, therefore lies in the multiobjective approach [4, 5] to problem solving. The solution of multiobjective optimization gives a number of solutions called noninferior solutions. In this paper, the objectives considered for optimal power dispatch are – cost of generation (F_C) and transmission losses (F_L).

The economic dispatch problem is to minimize the overall generating cost which is the function of plant output given by

$$F_C(P_i)=\Sigma a_i P_i^2 + b_i P_i + c_i \qquad (i=1,2,.......,NG) \qquad (1)$$

Where

F_C - the cost of generation,

P_i - Real power generation and is the decision variable

a_i, b_i, c_i - cost coefficients

Subject to the constraints that generation should equal total demand plus losses, i.e.

$$\Sigma P_i=P_D+P_L \qquad (2)$$

P_D – Power demand of generating plant, P_L – power losses of generating plant
Satisfying the inequality constraints, expressed as follows:

$$P_{i(max)} \le P_i \le P_{i(min)} \qquad (i=1,2,\ldots\ldots,NG) \qquad (3)$$

Where $P_{i(min)}$ and $P_{i(max)}$ are the minimum and maximum generating limits respectively, for i^{th} plant.

The ideal situation where one would like to operate the power systems is one where all the objectives are minimize. But this is not feasible due to conflicting nature of objectives. Therefore, one can achieve a point which is noninferior and at the minimum distance from the ideal point. Such a point is known as the **Target Point (TP) or the best compromise solution.**

The multiobjective techniques give us a number of non-inferior solutions, all of which are candidates for optimal solution. In this paper, the weighting method [6] using GA technique is used to generating the noninferior solutions in 2D space of IEEE 5, 14, and 30 bus systems. Such analysis, the power system operation point can be determined. The distance of all the feasible operating points (noninferior solutions) from the ideal power system operation point is calculated and the optimal power system operation is one for which this distance is minimum. This method directly gives the best compromise solution.

II. Tool (GA tool) in MATLAB

Our objective in this work is to solve multiobjective optimal power dispatch (MOPD) problem by using minimum distance method with the help of GA tool. Genetic algorithm software extends the optimization capabilities in MATLAB R2008b optimization toolbox. GA tool uses these algorithms for problems that are difficult to solve with traditional optimization techniques, including problems that are not well defined or are difficult to model. Mathematically, GA is also used when computation of the objective function is discontinuous, highly nonlinear, stochastic, or has unreliable or undefined derivatives.

III. Formulation of MOPD Problem

Two aspects of the optimal power dispatch (OPD) problem considered in 2D space are:
(i) To minimize the cost of generation.

(ii) To minimize the system transmission losses.
The objective function to minimize the cost of generation is given as

$$F_C = \sum_{i=1}^{NG} [C_i\,(P_{gi})] \qquad (i=1,2,\ldots\ldots.,NG) \qquad (4)$$

Where P_{gi} is the power generation at the ith generator, C_i is the cost of generation for i^{th} generator and NG is the total number of generators in the system.

The objective function to minimize the system transmission losses is defined as:

$$F_L = \Sigma\Sigma P_i B_{ij} P_j \qquad (5)$$

Where, B_{ij} = Loss coefficients.
i=1, 2,……,NG
j=1, 2,……,NG
NG = the number of generators.

IV. Ideal distance minimization method

This method [7] employs the concept of an 'Ideal Point' (IP). It's scalarized the problems having multiple objectives and minimizes the Euclidean distance between the IP and the set of feasible or noninferior solutions.

In 2D space, the multiobjective function comprises of cost of generation and system transmission losses i.e.

$$F = [F_C, F_L] \tag{6}$$

To generate the noninferior solution of multiobjective optimization problem, the weighting method is used. In this method the problem is converted into a scalar optimization problem as Minimize

$$F=W_C F_C+W_L F_L \tag{7}$$

Where

F_C is the cost of generation.

W_C is the weight attached to cost of generation.

F_L is the system transmission loss.

W_L is the weight attached to system transmission losses.

The ideal situation where one would like to operate the power system is the one where both objectives namely cost of generation (F_C) and system transmission loss (F_L) are minimum. In 2D space, the point having coordinator (F_{Cmin}, F_{Lmin}) represents the Ideal Point (IP). In order to locate Target Point in 2D space, the following distance function is proposed:

$$Distance=[(F_C-F_{Cmin})^2+(F_L-F_{Lmin})^2]^{1/2} \tag{8}$$

Where

F_{Cmin} – The value of cost of generation obtained by individually minimizing F_C.

F_{Lmin} – The value of system transmission losses obtained by individually minimizing F_L.

V. Results

The noninferior set is generated in 2D space by varying the weights attached to the objective function defined by equation (7). It is shown in Tables 1, 2, and 3 for IEEE 5-bus, 14-bus and 30-bus systems respectively.

It is observed that the range of transmission losses is very small compared to that of cost of generation. Therefore, the range of system transmission losses has been multiplied by the ratio R_C/R_L which makes the range of system transmission losses numerically almost equal to that of cost of generation.

Where

R_C = range of cost of generation= $F_{CatFLmin}$ - F_{Cmin}

R_L = Range of system transmission losses = $F_{LatFcmin}$ - F_{Lmin}

F_{Cmin} - The value of cost generation obtained by individually minimizing F_C.

F_{Lmin} - The value of system transmission losses obtained by individually minimizing F_L.

$F_{CatFLmin}$ -The value of cost generation obtained by individually minimizing $F_{L.}$

$F_{LatFcmin}$ - The value of system transmission losses obtained by individually minimizing $F_{C.}$

5.1 Distance function for IEEE 5-bus system:

From Table–1, it is observed that

R_C = 763.1833 – 760.951 = 2.2323

R_L = 5.1812 – 5.0582 = 0.1230

$R_C / R_L = 18.14$

The distance function for 5-bus is

$$Distance1=[(F_C-F_{Cmin})^2+18.14*(F_L-F_{Lmin})^2]^{1/2} \qquad (9)$$

The distance of each of the noninferior point is calculated by equation (9) and the result is shown in the last column of Table-1.

Table-1Results of MOPD studies by varying weights in 2D space (IEEE 5-bus system)

S.No.	W_C	W_L	F_L	F_C	distance
1	0	1	5.0582	763.1833	0.022323
2	1	0	5.1812	760.951	0.022324
3	1	0.01	5.1811	760.9597	0.022307
4	1	0.05	5.1805	760.9628	0.022198
5	1	0.1	5.1798	760.9614	0.022071
6	1	0.5	5.1745	760.9595	0.021109
7	1	1	5.1684	760.9644	0.020002
8	1	10	5.1088	761.2431	0.009637
<u>9</u>	<u>1</u>	<u>20</u>	<u>5.0856</u>	<u>761.57</u>	<u>0.00794</u>
10	1	30	5.0753	761.8217	0.009244
11	1	40	5.0699	762.0106	0.010807
12	1	50	5.0667	762.1547	0.012135
13	1	60	5.0647	762.2672	0.013215
14	1	70	5.0633	762.3545	0.014065
15	1	80	5.0623	762.4329	0.014838
16	1	90	5.0615	762.4886	0.015388
17	1	100	5.061	762.5433	0.015931
18	10	0.01	5.1811	760.9597	0.022307
19	10	0.05	5.1811	760.9597	0.022307
20	10	0.1	5.181	760.9601	0.022288
21	10	0.5	5.181	760.9604	0.022288
22	10	1	5.1797	760.9615	0.022052
23	10	10	5.1684	760.9644	0.020002
24	10	20	5.1577	760.984	0.018062
25	10	30	5.1483	761.0039	0.016362
26	10	40	5.1403	761.0321	0.014923
27	10	50	5.1333	761.0637	0.013677
28	10	60	5.1271	761.0982	0.012592
29	10	70	5.1217	761.1353	0.011672
30	10	80	5.1169	761.1704	0.010878
31	10	90	5.1126	761.2036	0.010192
32	10	100	5.1087	761.2392	0.009608

Noninferior set for IEEE 5-bus has been shown in graph of Fig.1. It has been plotted from Table-1 between transmission loss function (as X- axis) and cost of generation function (Y-axis). IP shows the Ideal Point which is infeasible and TP shows the Target Point or the best compromise solution which is at minimum distance from Ideal Point.

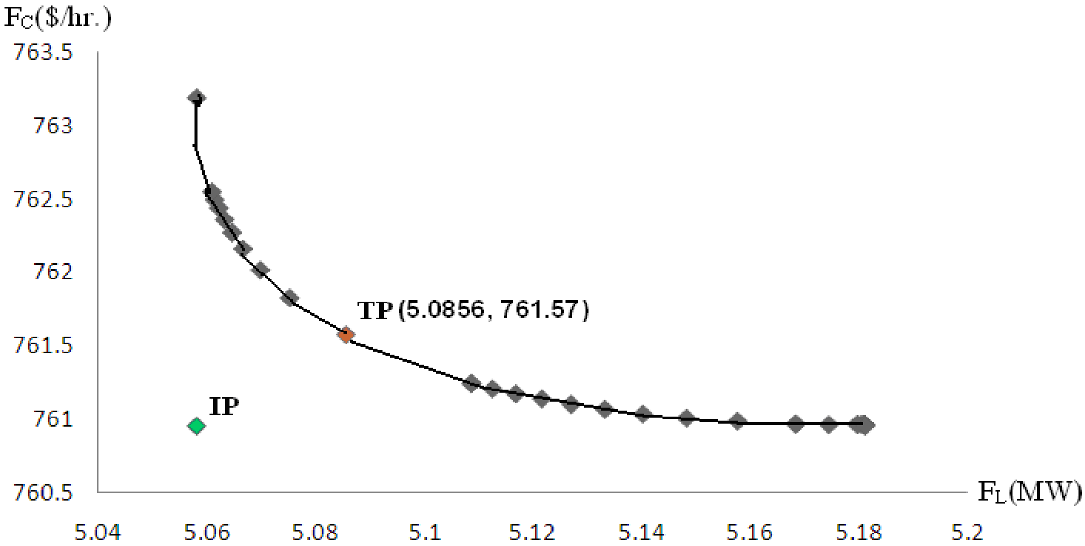

Fig.1: Noninferior set of IEEE 5-Bus system in 2D space

It is observed from the graph that at Target Point:
Cost of generation is F_C^* = 761.57 \$/hr
Transmission losses is F_L^* = 5.0856 MW
Hence the Target Point is (F_C^*, F_L^*) or (761.57, 5.0856) and the minimum distance from Ideal Point (760.9515, 0.0582) to Target Point (761.57, 5.0856) is 0.00794. It is shown at S.No. 9 of Table-1.

5.2 Distance function for IEEE 14-bus system:
From Table–2, it is observed that
$R_C = 1189 – 1137.5 = 51.5$
$R_L = 8.7 – 7.4 = 1.3$
$R_C / R_L = 39.62$

The distance function for 14-bus is
$$\text{Distance2}=[(F_C-F_{Cmin})^2+39.62*(F_L-F_{Lmin})^2]^{1/2} \qquad (10)$$
The distance of each of the noninferior point is calculated by (10) and the result is shown in the last column of Table-2.

Table-2 Results of MOPD studies by varying weights in 2D space (IEEE 14-bus system)

S.No.	W_C	W_L	F_L	F_C	distance
1	0	1	7.4	1189	0.515
2	1	0	8.7	1137.5	0.5151
3	1	0.01	8.7	1137.5	0.5151
4	1	0.05	8.7	1137.5	0.5151
5	1	1	8.6	1137.8	0.4754
6	1	5	8.6	1137.8	0.4754
7	1	10	8.4	1139.6	0.3968
8	1	20	8	1142.1	0.2421
9	1	25	7.9	1144.6	0.2104

10	**1**	**40**	**7.7**	**1152.8**	**0.1937**
11	1	55	7.6	1157.5	0.2179
12	1	60	7.6	1158.8	0.2273
13	1	90	7.5	1164.8	0.2759
14	1	95	7.5	1165.6	0.2838
15	10	0	8.7	1137.5	0.5151
16	10	1	8.7	1137.5	0.5151
17	10	0.01	8.7	1137.5	0.5151
18	10	0.05	8.7	1137.5	0.5151
19	10	0.1	8.7	1137.5	0.5151
20	10	0.5	8.7	1137.5	0.5151
21	10	1	8.7	1137.5	0.5151
22	10	5	8.7	1137.5	0.5151
23	10	10	8.7	1137.5	0.5151
24	10	15	8.7	1137.5	0.5151
25	10	20	8.7	1137.5	0.5151
26	10	25	8.7	1137.5	0.5151
27	10	30	8.7	1137.5	0.5151
28	10	35	8.7	1137.5	0.5151
29	10	45	8.6	1137.7	0.4754
30	10	50	8.6	1137.8	0.4754
31	10	55	8.6	1137.9	0.4755
32	10	60	8.6	1138	0.4358
33	10	65	8.6	1138.1	0.4755
34	10	70	8.5	1138.2	0.4359
35	10	75	8.5	1138.5	0.4359
36	10	80	8.5	1138.7	0.436
37	10	85	8.5	1138.9	0.436
38	10	90	8.4	1139.2	0.3966
39	10	95	8.4	1139.4	0.3967
40	10	100	8.4	1139.6	0.3968

Noninferior set for IEEE 14-bus has been shown in graph of Fig.2. It has been plotted from Table-2 between transmission loss function (as X- axis) and cost of generation function (Y-axis). IP shows the Ideal Point which is infeasible and TP shows the Target Point or the best compromise solution which is at minimum distance from Ideal Point. (F_C*, F_L*).

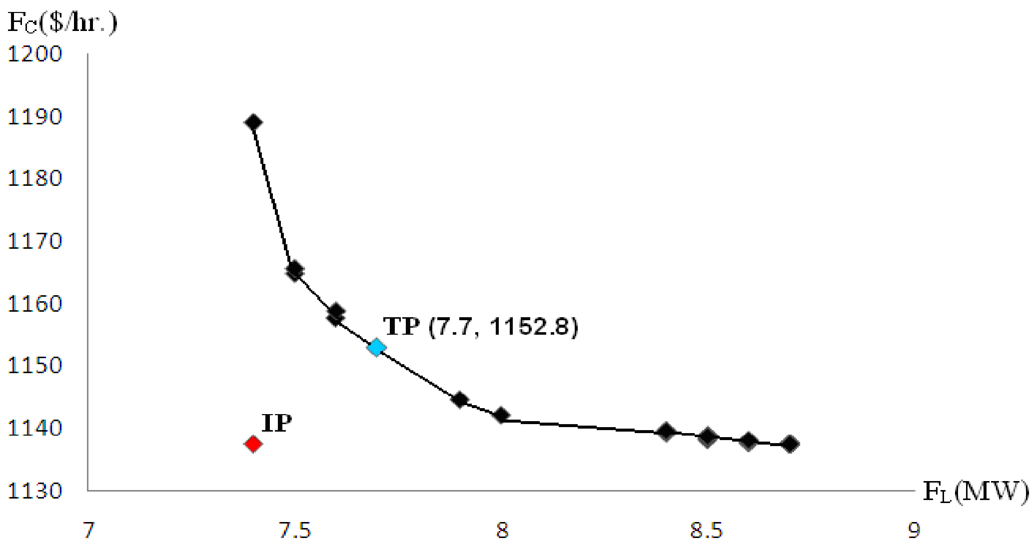

Fig.2: Noninferior set of IEEE 14-Bus system in 2D space

It is observed that at Target Point:
Cost of generation is $F_C^* = 1152.8$ $/hr
Transmission losses is $F_L^* = 7.7$ MW
Hence the Target Point is (F_C*, F_L*) or (1152.8, 7.7) and the minimum distance from Ideal Point (1137.5, 7.4) to Target Point (1152.8, 7.7) is 0.1937. It is shown at S.No.10 of Table-2.

5.3 Distance function for IEEE 30-bus system:
From Table–3, it is observed that
$R_C = 1361.2 – 1257.1 = 104.1$
$R_L = 11.8 – 7 = 4.8$
$R_C / R_L = 21.7$

The distance function for 30-bus is
$$\text{Distance3}=[(F_C-F_{Cmin})^2+21.7*(F_L-F_{Lmin})^2]^{1/2} \quad (11)$$

The distance of each of the noninferior point is calculated by (11) and the result is shown in the last column of Table-3.

Table-3
Results of MOPD studies with varying weights in 2D space
(IEEE 30-bus system)

S.N0.	W_C	W_L	F_L	F_C	Distance
1	0	1	7	1361.2	1.041
2	1	0	11.8	1257.1	1.0416
3	1	0.01	11.8	1257.1	1.0416
4	1	0.05	11.8	1257.1	1.0416
5	1	0.1	11.8	1257.1	1.0416
6	1	1	11.7	1257.1	1.0199
7	1	5	10.8	1260.2	0.8252

8	1	10	9.8	1267.4	0.6163
9	1	15	9.2	1275.4	0.5113
10	**1**	**20**	**8.7**	**1283.3**	**0.4525**
11	1	25	8.4	1290.7	0.453
12	1	30	8.1	1297.6	0.4701
13	1	35	7.9	1303.9	0.5071
14	1	40	7.8	1309.8	0.5549
15	1	45	7.6	1315.2	0.5954
16	1	50	7.5	1320.1	0.6393
17	1	55	7.4	1324.7	0.6816
18	1	60	7.4	1329	0.7242
19	1	65	7.3	1333	0.7618
20	1	70	7.3	1336.6	0.7977
21	1	75	7.2	1340.1	0.8311
22	1	80	7.2	1340.1	0.8311
23	1	85	7.1	1346.3	0.8923
24	1	90	7.1	1349.1	0.9204
25	1	95	7.1	1351.8	0.9203
26	1	100	7	1354.3	0.9472
27	10	0	11.8	1257.1	1.0416
28	10	0.01	11.8	1257.1	1.0416
29	10	0.5	11.8	1257.1	1.0416
30	10	0.1	11.8	1257.1	1.0416
31	10	10	11.7	1257.1	1.0199
32	10	15	11.7	1257.2	1.0199
33	10	20	11.6	1257.2	0.9982
34	10	25	11.5	1257.6	0.9765
35	10	30	11.3	1258	0.9331
36	10	35	11.2	1258.5	0.9115
37	10	40	11.1	1259	0.8899
38	10	45	10.9	1259.8	0.8467
39	10	50	10.8	1260.2	0.8252
40	10	55	10.7	1260.8	0.8038
41	10	60	10.6	1261.5	0.7824
42	10	65	10.4	1262.9	0.7401
43	10	70	10.3	1262.9	0.7184
44	10	75	10.2	1263.6	0.6974
45	10	80	10.1	1264.3	0.6765

46	10	85	10.1	1265.1	0.6774
47	10	95	9.9	1266.6	0.6364
48	10	100	9.8	1267.4	0.6163

Noninferior set for IEEE 30-bus has been shown in graph of Fig.3. It has been plotted from Table-3 between transmission loss function (as X- axis) and cost of generation function (as Y- axis). IP shows the Ideal Point which is infeasible and TP shows the Target Point or the best compromise solution which is at minimum distance from Ideal Point (F_C*, F_L*).

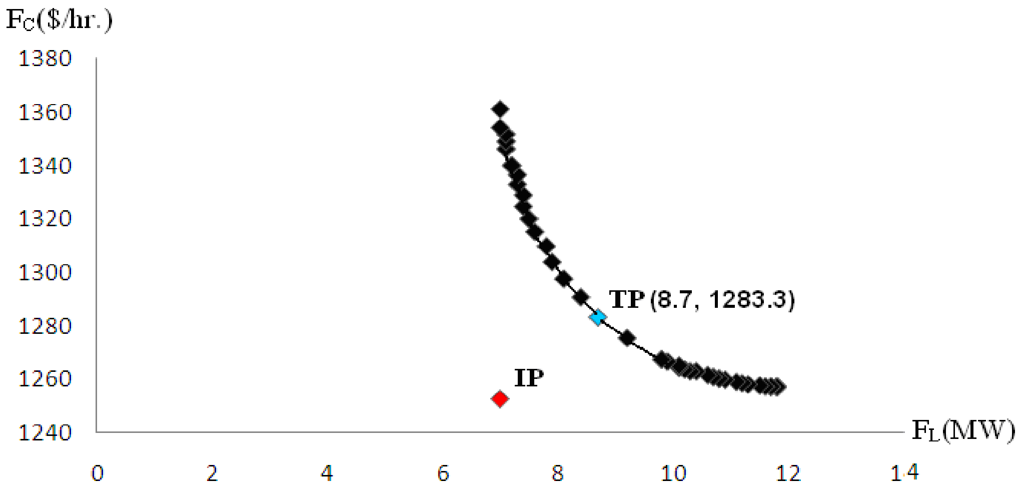

Fig.3: Noninferior set of IEEE 30-Bus system in 2D space

Observation at the Target Point:
Cost of generation is F_C* = 1283.3 $/hr
Transmission losses is F_L* = 8.7 MW
Hence the Target Point is (F_C*, F_L*) or (1283.3, 8.7) and the minimum distance from Ideal Point (1257.1, 7) to Target Point (1283.3, 8.7) is 0.4525. It is shown at S.No.10 of Table-3.

VI. Discussions

From Table-1, it is observed that for IEEE 5-bus system the Target Point (TP) is achieved when W_C=1.0 and W_L=20. Similarly, for IEEE 14-bus system, the TP is achieved when W_C=1.0 and W_L=40. Also, for IEEE 30-bus system the weights at the TP are: W_C=1.0 and W_L=20. These can be considered as the optimal weights, which when attached to the objective function will give TP in single step. The optimal weights and the TP for IEEE 5-bus, 14-bus and 30-bus systems are summarized in Table-4.

Table-4
Optimal weights and Target Points

IEEE system	W_C	W_L	F_C*($/hr.)	F_L*(MW)
5-bus	1.0	20	761.57	5.0856
14-bus	1.0	40	1152.8	7.7
30-bus	1.0	20	1283.3	8.7

The analysis of Table-4 shows that in order to achieve the Target Point (TP), W_C is should be kept fixed to 1.0 where as W_L should be varied from 20 to 40.

VII. Conclusions

The focus of this paper work concentrates on simultaneously minimization of two objectives of power system – cost of generation and transmission loss using weighting method and Formulation of solution methods to obtain the optimum solution of Multiobjective optimal power dispatch (MOPD) problem has been implemented successfully using weighting method with the help of GA tool.

The noninferior set for IEEE 5, 14 and 30 bus systems has been obtained by parametrically varying weights attached to each of the objectives in the objective function and Target Point (TP) or best compromise solution is obtained by Minimum Distance Method.

It has been observed that Target Point for IEEE 5-bus, 14-bus and 30-bus systems can be achieved, if the weight attached to cost of generation (W_C) is kept fixed to 1.0 (one), where as the weight attached to the system transmission loss (W_L) is varied from 20 to 40.

The weights at which the Target Point is achieved have been determined for IEEE 5-bus, 14-bus and 30-bus systems. These are called the optimal weights. If the optimal can be derived weights and the Target Point or the best compromise solution can achieve be in a single step which will save lot of computational effort.

It has been observed that the optimal weights in all the cases were almost equal to the ratio of R_C/R_L. The minimum distance technique has no limitation in handling more than two objectives.

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