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Application of a New Meta-heuristic Algorithm using Egyptian Vulture Optimization for Economic

***Abstract**. The industrialization and the growth of the population are the first factors for which the consumption of electrical energy increases regularly, which implies an increase of the cost and a degradation of the natural environment, so we need to solve the technical and economic dispatching problems. This paper presents, for the first time, the basis of EVOA approach in economic dispatching problems (EDP).,This approach is proposed to solve the non-convex and non-continuous EDP., The effectiveness of the proposed method is examined and validated by carrying out extensive test systems using three, six and fifteen generating units. Numerical results show that the EVOA method has a good convergence property, The result shows that the proposed method can reliably handle complex objective optimization problems in strong and effective way the generation costs tested by the EVOA method are lower than other optimization algorithms reported in literature.*

Streszczenie.** W artykule zaprezentowano podstawy metody EVOA zastosowanej do rozwiązania problemu ekonomicznego rozsyłu energii EDP. Metoda stosowana jest do rozwiązania problemu nieciągłego EDP. Sprawdzono ją dla układów 3, 6 I 15 generatorów. **Zastosowanie nowego meta-heurystycznego algorytmu egipskiego sępa do optymalizacji ekonomicznego rozsyłu energii

Keywords: Egyptian Vulture Optimization; Algorithm Economic dispatch problem; electric power generation.
Słowa kluczowe: algoytm Egiposki sęp, ekonomiczny rozsył energii

Introduction

The industrialization and the growth of the population are the first factors for which the consumption of electrical energy increases regularly. As well, to have a balance between production and consumption, it is at first sight necessary to increase the number of power plants, lines, transformers etc[1], which implies an increase of the cost and a degradation of the natural environment. Accordingly, it is important today to have of mesh networks and work close to the limits of stability [2]-[5].

The exploitation of electrical networks requires to improve the management of energy by introducing the costs of production and minimizing the transmission losses. Scientific research is oriented toward the best form of economic distribution of electrical energy in order to minimize the costs of production [6]-[10].

For a good operation of the network, we need to solve the problems of a technical and economic, which requires the improvement of the management of electrical energy by reducing the cost of production and on the other hand by keeping the balance between production and consumption [11]. The current objective of an economic dispatch is the electrical production with a low cost of fuel. The general problem of the production and the optimal distribution of powers in a production system -Transport- consumption are therefore very complex.

Several methods like PSO [12], bat algorithm [13], [14], Honey bee swarm [15]-[18] league championship algorithm [19], [20], cuckoo search [21], simulated annealing [22], [23], krill herd optimization [24]-[29],Virus Optimization Algorithm [30]-[32], Magnetic Optimization Algorithms [21], [23], etc, have been developed to resolve this problem

Here, a new meta-heuristic technique Egyptian Vulture Optimization [33], [34] is implemented to solve economic dispatch problems, and present its effectiveness using three, six, fifteen and forty generating units test systems. The result shows that the proposed methodology can reliably handle complex objective optimization problems in strong and effective way.

This paper presents, for the first time, the basis of EVOA approach in economic dispatch problems, we obtain very satisfactory results (cost, P_L) compared with results of previous studies relied on other methods.

Principle of economic distribution of powers

We consider a production-transport network at n node where we have ng generator nodes. The function of the total cost of production of this network is given by the following form [8], [11], [14]:

$$F_{glob} = \sum_{i=1}^{ng} F_i\left(P_{gi}\right) \tag{1}$$

with: P_{gi}: Represents the active powers generated; ng :Represents the number of nodes generators; F_i (P_{gi}):Represents the cost of production of the central i; F_{glob} : Represents the sum of the functions of the cost of each central.

The problem of the economic distribution of powers is to minimize the function of the total cost of fuel necessary for the production of energy requested.
This function is given by a polynomial of degree (n) in the following general form:

$$F\left(P_g\right) = a_0 + a_1 P\,g + a_2 P_g^2 + ... + a_n P_g^n \tag{2}$$

The coefficients of the latter are calculated using one of the methods of interpolation, but in practice, this equation is in the form of a polynomial of the second degree, that is to say:

$$F\left(P_g\right) = c + bP_g + aP_g^2 \tag{2}$$

So we can write the cost function for the ith generator node as follows:

$$F_i\left(P_{gi}\right) = c_i + b_i P_{gi} + a_i P_{gi}^2 ....i = 1,....,ng \tag{4}$$

a_i, b_i, c_i : Represents the coefficients of the cost function specific to the central (i) [12], [25]. It is therefore, at this stage that the problem of the optimal allocation of powers arises, it can be represented as follows**:**

It is necessary to minimize the cost of electrical energy for the whole of units:

(5) $$\mathrm{Min}\left\{F_{\mathrm{glob}}\left(P_{\mathrm{gi}}\right)=\sum_{\mathrm{i=1}}^{\mathrm{ng}}F_{\mathrm{i}}\left(P_{\mathrm{gi}}\right)\right\}$$

Under the following constraints:
Equality constraints

(6) $$\sum_{\mathrm{i=1}}^{\mathrm{ng}}P_{\mathrm{gi}}=\sum_{\mathrm{i=1}}^{\mathrm{ng}}P_{\mathrm{D}}+P_{\mathrm{L}}$$

The constraints of inequality

(7) $$P_{\mathrm{gi}}^{\min}\leq P_{\mathrm{gi}}\leq P_{\mathrm{gi}}^{\max}$$

with: n : Total number of nodes; P_{gi} : Active power produced by the ith generator node; P_D: Active power consumed by ith load; P_L : Losses total active in the network; $P_{\mathrm{gi}}^{\max}$: Maximum active power produced by ith generator; $P_{\mathrm{gi}}^{\min}$: Minimum active power produced by ith generator.

The effect of transmission losses is to express the total transmission loss as a quadratic function of the generator power outputs, the transmission loss may be expressed using b-coefficients as [4,35]:

(8) $$P_{\mathrm{L}}=\sum_{\mathrm{i=1}}^{\mathrm{N}}\sum_{\mathrm{j=1}}^{\mathrm{N}}p_{\mathrm{i}}B_{\mathrm{ij}}p_{\mathrm{j}}$$

Kron's loss formula:

(9) $$P_{\mathrm{L}}=\sum_{\mathrm{i=1}}^{\mathrm{N}}\sum_{\mathrm{j=1}}^{\mathrm{N}}p_{\mathrm{i}}B_{\mathrm{ij}}p_{\mathrm{j}}+\sum_{\mathrm{j=1}}^{\mathrm{N}}B_{0\mathrm{j}}p_{\mathrm{j}}+B_{00}$$

where B_{ij} is the ijth element of the loss coefficient square matrix, B_{0j} is the jth element of the loss coefficient vector, and B_{00} is the loss coefficient constant [36].

Description of EVOA [33].

The EVOA is a new member in the family of Meta-Heuristics, this method of some given phases, using representation by illustrations and explications. The two principal actions of the Egyptian Vulture, which are taken into account here or by preference to turn over into algorithm, are the throwing of gravel and the capacity of turn round and round objects with twigs.

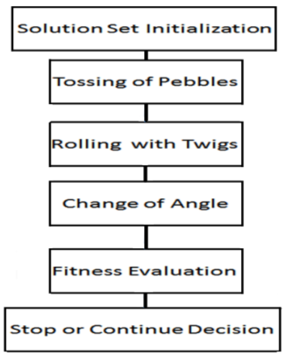

Fig .1. EVOA's organizational chart

The nature has developed many methods to protect it balance and elements, the Egyptian vulture is one of these elements, needs during feeding to bird's eggs, which are protected with solid covers, the Egyptian vulture made many attempts using throwing gravels before succeeding in breaking egg's cover by changing –randomly- in every attempt the throwing angle and/or the throwing force. The EVOA process is applied to minimize gas emissions in the electric power stations. Figure 1; illustrate the EVOA's organizational chart [34].

A Simplified Explanation Of The EVOA:
Phase 1: Initiation
Phase 2: Take randomly the maximum possible of value n which Achieve the condition
Phase 3: validation of value n in Function F

$$P_{\mathrm{gi\,min}}\leq P_{\mathrm{gi}}\leq P_{\mathrm{gi\,max}}$$

Phase 4: Classification of solutions from the minimum till maximum
Phase 5: Take a certain Percentage xi of solutions

Simulation results

Experimentally, In order to evaluate the efficacy of Egyptian Vulture Optimization Algorithm, it use a system composed of three units, this process is repeated with six units, and finally with fifteen units. The process proposed (EVOA) perform the Matlab to obtain solutions.

Application 1:

The application of the EVOA has been made on an IEEE network of three generators of production; which possess a cost function to this production. The parameters related

Table 1. Data of three generators of production

Unit	$P_{gi}^{\min}$	$P_{gi}^{\max}$	*a_i($/MW^2)*	*b_i($/MW)*	*c_i($)*
1	100	600	0.001562	7.92	561
2	50	200	0.004820	7.97	78
3	100	400	0.001940	7.85	310

Table 2. System of three units simulated by EVOA and four other processes

Method	**P_1**	**P_2**	**P_3**	**P_D(MW)**	**cost ($/h)**
FSS-PSO [37]	349.4662	400.0000	100.5338	**850.000**	**8220.9327**
EP [38]	300.264	149.736	400.000	**850.000**	**8234.07**
EP-SQP [38]	300.267	149.733	400.000	**850.000**	**8234.07**
PSO [38]	300.268	149.732	400.000	**850.000**	**8234.07**
PSO-SQP [38]	300.267	149.733	400.000	**850.000**	**8234.07**
GAB[39]	-	-	-	**-**	**8234.08**
GAF[39]	-	-	-	**-**	**8234.07**
CEP [39]	-	-	-	**-**	**8234.07**
FEP [39]	-	-	-	**-**	**8234.07**
MFEP [39]	-	-	-	**-**	**8234.08**
IFEP [39]	-	-	-	**-**	**8234.07**
GAB[39]	-	-	-	**-**	**8234.05**
PS [40]	300.2663	149.7331	399.9996	**849.9990**	**8234.1**
GSA [41]	300.2102	149.7953	399.9958	**850.0013**	**8234.0724**
ABC [42]	300.2656	149.7344	400.0000	**850.000**	**8222.07**
TLBO [43]	394.5243	56.2764	399.1993	**850.000**	**8280.9**
Proposed EVOA	422.6183	91.7024	335.6793	**850.000**	**8200.2069**

The table 2 present an optimum simulation results of EVOA EDP compared with simulation results of GA, EP, EP-SQP, PSO, PSO- SQP, GAB, GAF,CEP,FEP, MFEP, IFEP, GAB, PS, GSA, ABC , and TLBO , where the charge is modified as follows: P_D=850MW.The results obtained by EVOA are satisfactory when compared with other processes Figure 2.

Variations of fuel cost in terms of number of iterations with EVOA for power demand of 850MW are plotted in figure3 the proposed EVOA reduces the cost of electrical power generate.

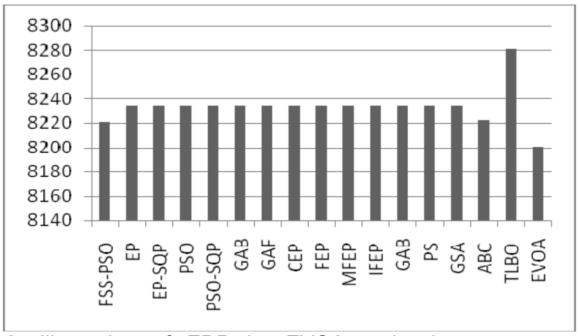

Fig.2. Illustration of EDP by EVOA and other processes in application 1

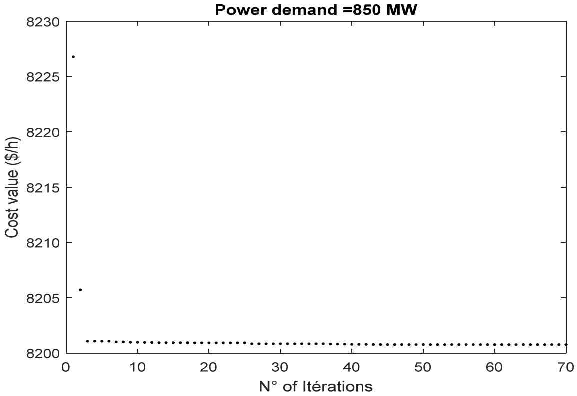

Fig. 3. Convergence of three generating unit system for P_D=850MW

Table 3 shows the summarized result of EDP for load demand of 400MW, 500MW, 600 and 700MW are obtained by the proposed EVOA algorithm with stopping criteria based on maximum-generation=70.

Table 3. Economic dispatch results for 3-unit system

	Power demand (MW)			
Unit (MW)	**400**	**500**	**600**	**700**
P_1	188.6293	236.1234	291.6813	341.5761
P_2	62.6147	57.73687	90.0883	93.7271
P_3	148.7562	206.1397	218.2304	264.6967
Total output	**400.000**	**500.000**	**600.000**	**700.000**
cost ($/h)	**4227.1308**	**5083.0505**	**5954.6373**	**6839.6710**
T (S)	**3.423 s**	**3.542 s**	**3.658 s**	**3.717 s**

Variations of fuel cost in terms of number of iterations with EVOA for power demand of 400MW, 500MW, 600MW, and 700 MW are plotted in figure 4, figure 5, figure 6 and figure 7,the proposed EVOA reduces the cost of electrical power generate.

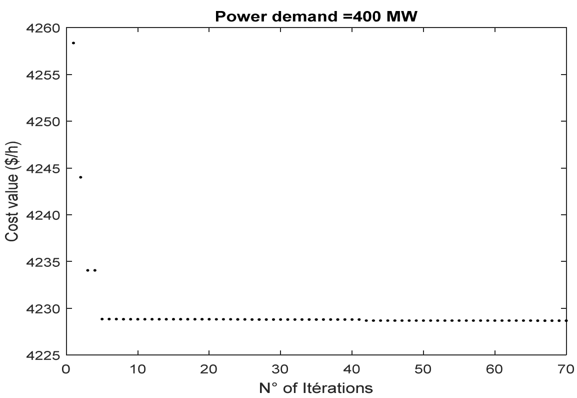

Fig.4. Convergence of three generating unit system for P_D= 400 MW

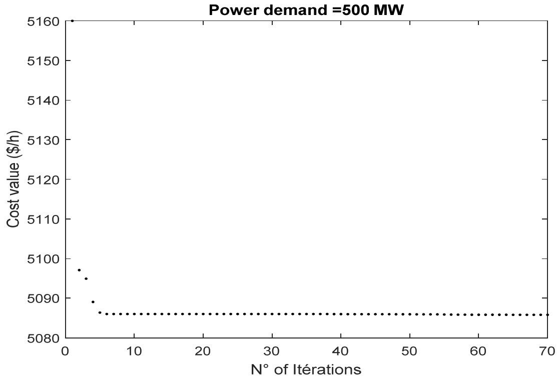

Fig 5. Convergence of three generating unit system for P_D=500 MW

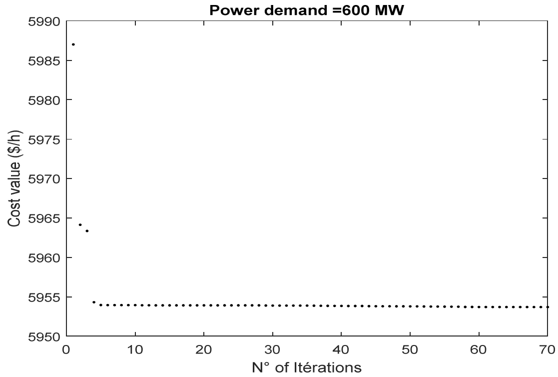

Fig.6. Convergence of three generating unit system for P_D=600 MW.

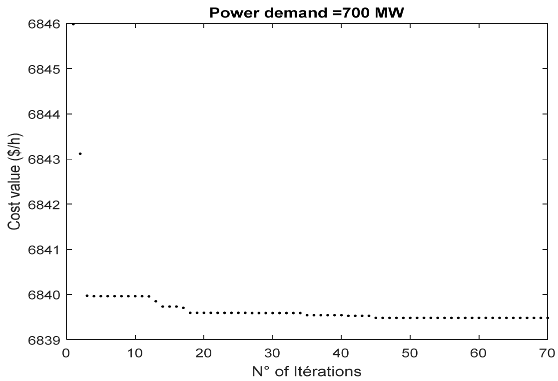

Fig.7. Convergence of three generating unit system for P_D=700 MW.

The EVOA has therefore well given satisfactory results. This demonstrates that it is much faster and more efficient than similar techniques in dealing with the problems of objective optimization.

Application 2:

The application of the EVOA has been made on an IEEE network of six generators of production; which possess a cost function to this production. The parameters related by the system composed of six units are indicated in the table 4.

Table 4. Generating unit capacity and coefficients for six unit system

Unit	$P_{ig}^{\min}$	$P_{ig}^{\max}$	a_i($/MW^2)	b_i($/MW)	c_i($)
1	100	500	0.0070	7.0	240
2	50	200	0.0095	10.0	200
3	80	300	0.0090	8.5	220
4	50	150	0.0090	11.0	200
5	50	200	0.0080	10.5	220
6	50	120	0.0075	12.0	190

Table 5. Economic dispatch results for six unit system.

Unit / Method	P_1(MW)	P_2(MW)	P_3(MW)	P_4(MW)	P_5(MW)	P_6(MW)	**Total output**	**Loss (MW)**	**Cost ($/h)**
EVOA	438.1003	175.031	277.8132	129.9183	175.6926	78.48954	1275,046	12.04619	**15442.875**
HBB-BC [44]	441.36	175.68	262.82	134.57	169.98	91.16	1275.57	12.57	**15444.26**
FSS-PSO [37]	446.2766	172.3898	265	142.5145	162.9183	86.2179	1275.3171	12.3171	**15442.9219**
BFO[46]	449.4600	172.880	263.4100	143.4900	164.9100	81.2520	1275.402	12.4020	**15443.849**
PSO [47]	440.58	167.44	278.24	150	157.60	81.22	1275.07	12.08	**15445.48**
E-PSO [48]	447.389	173.234	263.372	138.972	165.384	87.044	-	12.394	**15442.89**
HHS[49]	447.4960	173.314	263.4450	139.0550	165.4750	87.1250	1250.910	12.9500	**15449.000**
GA[50]	474.81	178.46	262.21	134.28	151.90	74.18	1276.02	13.02	**15459.0**
SCKF-PSO [45]	455.48	167.30	271.76	147.69	163.49	69.67	1275.8405	12.9643	**15441.2764**
IPSO[51]	440.5711	179.836	261.3798	131.9134	170.9823	90.8241	125.5072	12.5480	**15444.000**
IPSO-AC [52]	447.5840	173.201	263.3310	138.8520	165.3280	87.1500	1275.446	12.4460	**15443.063**
BSA[43]	447.4902	173.330	263.4559	139.0602	165.4804	87.1409	1275.958	12.9583	**15449.899**
HYB [53]	447.3335	173.255	263.3879	138.9444	165.3314	87.1908	1275.444	12.4445	**15443.07**

Tables 5 and 6 present an optimum simulation results of EVOA EDP compared with simulation results of HHB-BC,NPSO-LRS,BFO,NAPSO, SOH-PSO,HHS,GA,BB-BC, IPSO, IPSO-TVAC and BSA, where the charge is modified as follows: P_D=1263MW.

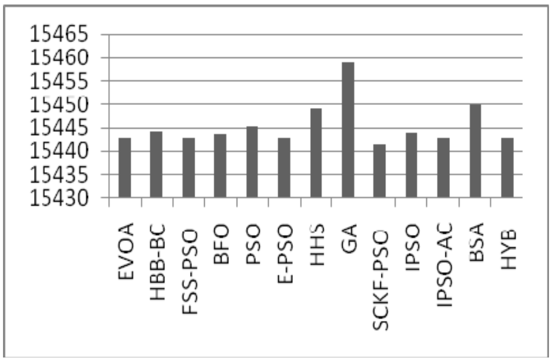

Fig.8. Illustration of EDP by EVOA and other processes in application 2

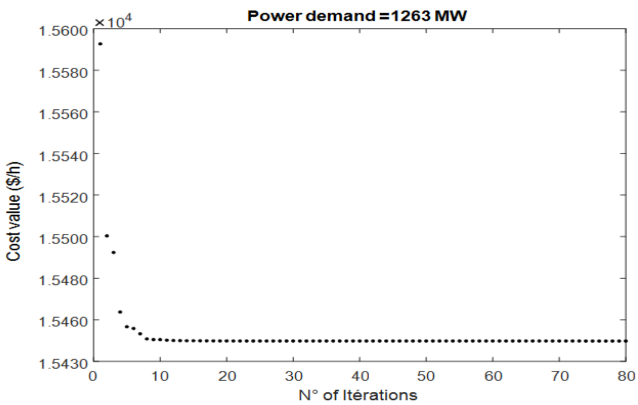

Fig.9. convergence of six generating unit system for P_D=1263MW

The results obtained by EVOA are satisfactory when compared with other processes figure 8.

Variations of fuel cost in terms of number of iterations with EVOA for power demand of 850MW are plotted in figure 9 the proposed EVOA reduces the cost of electrical power generate.

Table 6 shows the summarized result of EDP for load demand of 500MW, 700MW, 900 ,1100 and 1300MW are obtained by the proposed EVOA algorithm with stopping criteria based on maximum-generation=80.

Table 6. Test results for 6unit system

	EVOA Power demand (MW)				
Unit (MW)	**500**	**700**	**900**	**1100**	**1300**
P_1	169.2386	321.9659	325.1633	428.0582	455.7245
P_2	54.2475	77.8552	92.2204	145.8826	192.0882
P_3	100.969	112.1473	210.3230	243.4811	253.0900
P_4	50.8115	84.3814	96.7029	102.1142	135.0159
P_5	70.6323	54.7075	124.0804	119.4959	176.0057
P_6	56.1295	52.7384	57.9629	70.6265	101.3915
Total output	502.029	703.795	906.4531	1109.6588	1313.3161
Loss (MW)	**2.0295**	**3.795**	**6.45311**	**9.65888**	**13.31615**
cost ($/h)	**6168.57**	**8327.30**	**10707.16**	**13220.82**	**15882.325**

Variations of fuel cost in terms of number of iterations with EVOA for power demand of 500MW, 700MW, 900 ,1100 and 1300MW are plotted in figure 10, figure 11, figure 12 and figure 13,the proposed EVOA reduces the cost of electrical power generate.

The EVOA has therefore well given satisfactory results. This demonstrates that it is much faster and more efficient than similar techniques in dealing with the problems of objective optimization.

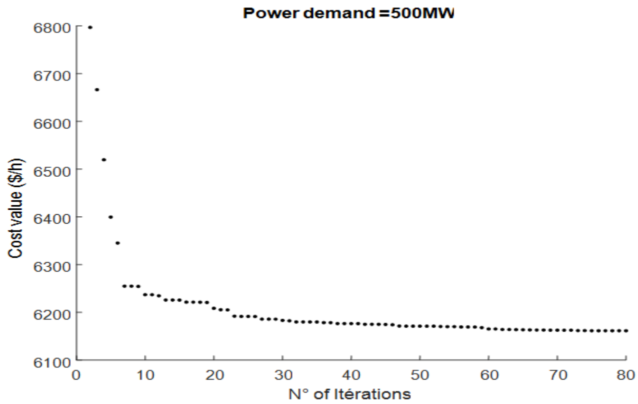

Fig.10. Convergence of six generating unit system for P_D=500 MW

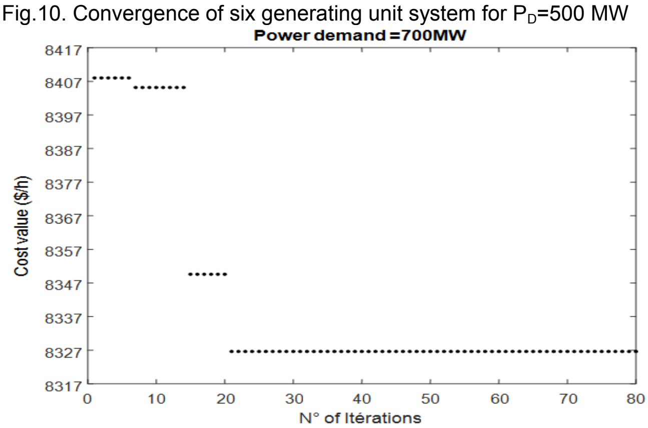

Fig.11. Convergence of six generating unit system for P_D=700 MW

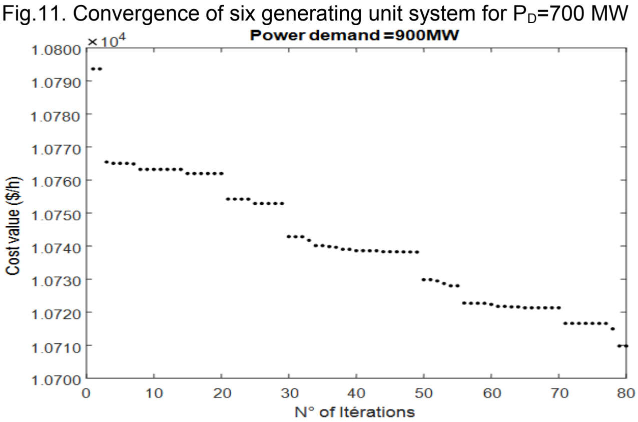

Fig.12. Convergence of six generating unit system for P_D=900 MW

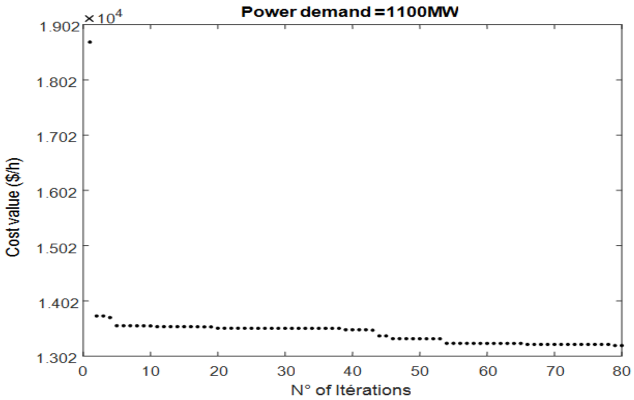

Fig.13. Convergence of six generating unit system for P_D=1100 MW

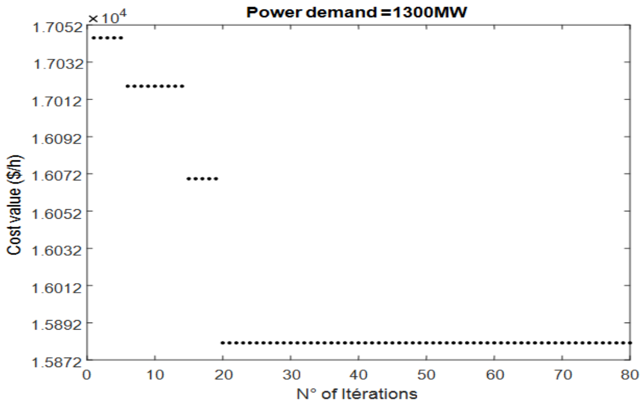

Fig 14. Convergence of six generating unit system for P_D=1300 MW

Application 3:

The application of the EVOA has been made on an IEEE network of fifteen generators of production; which possess a cost function to this production. The parameters related by the system composed of fifteen units are indicated in the table 7.

Table 7.Generating unit data for 15-unit system

Unit	$P_{gi}^{\min}$	$P_{gi}^{\max}$	*a_i($/MW^2)*	*b_i($/MW)*	***c_i($)***
1	150	455	0.000299	10.1	671
2	150	455	0.000183	10.2	574
3	20	130	0.001126	8.8	374
4	20	130	0.001126	8.8	374
5	150	470	0.000205	10.4	461
6	135	460	0.000301	10.1	630
7	135	465	0.000364	9.8	548
8	60	300	0.000338	11.2	227
9	25	162	0.000807	11.2	173
10	25	160	0.001203	10.7	175
11	20	80	0.003586	10.2	186
12	20	80	0.005513	9.9	230
13	25	85	0.000371	13.1	225
14	15	55	0.001929	12.1	309
15	15	55	0.004447	12.4	323

The table 8 presents an optimum simulation results of EVOA EDP compared with simulation results of FA GAAPI , BB–BC, PSO , IA_EDP, BSA and HBB–BC where the charge is modified as follows: P_D=2630MW.The results obtained by EVOA are satisfactory when other processes figure 15 compared with.

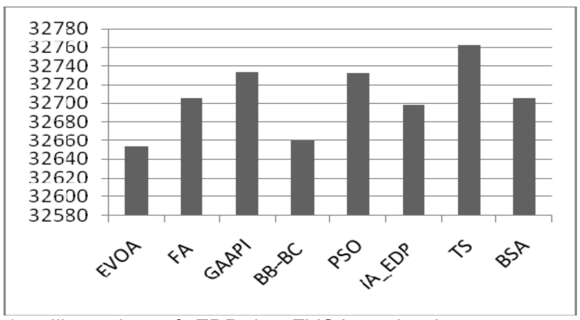

Fig.15. Illustration of EDP by EVOA and other processes in application 3

Variations of fuel cost in terms of number of iterations with EVOA for power demand of 2630MW are plotted in figure16 the proposed EVOA reduces the cost of electrical power generate.

Table 8. Economic dispatch results for 15-unit system

Unit (MW)	Proposed EVOA	FA [54]	GAAPI[55]	BB–BC [44]	PSO[55]	IA_EDP [57]	TS[58]	BSA[59]
P_1	416.7195	455	454.70	454.9991	455.000	455.0	453.5374	455.0000
P_2	455	380	380.00	455.0000	380.00	379.9999	371.9761	380.0000
P_3	130	130	130.00	130.0000	130.00	130.0	129.7823	130.0000
P_4	129.9194	130	129.53	130.0000	130.00	129.9999	129.3411	130.0000
P_5	308.550	170	170.00	227.1366	154.42	169.9999	169.5950	170.0000
P_6	354.0913	460	460.00	460.0000	460.00	459.9999	457.9928	460.0000
P_7	465	430	429.71	465.0000	430.00	429.9999	426.8879	430.0000
P_8	74.7620	71.745	75.35	60.0000	60.00	67.9628	95.1680	71.6368
P_9	80.6349	58.916	34.96	25.0000	74.27	65.7269	76.8439	59.0234
P_{10}	74.4878	160	160.00	160.0000	160.00	156.3294	133.5044	160.0000
P_{11}	79.6953	80	79.75	20.0000	80.00	80.0	68.3087	80.0000
P_{12}	34.1811	80	80.00	20.0000	79.60	79.9999	79.6815	80.0000
P_{13}	25.0035	25	34.21	25.0000	25.00	25.0000	28.3082	25.0001
P_{14}	15.0616	15	21.14	15.0000	27.59	15.000	17.7661	15.0001
P_{15}	15.0017	15	21.02	15.0000	15.00	15.000	22.8446	15.0005
Total output	**2658.109**	**2660.661**	**2660.36**	**2662.13**	**2660.88**	**2660.019**	**2661.53**	**2660.660**
Loss (MW)	**28.135**	**30.661**	**30.36**	**32.1358**	**30.88**	**30.0187**	**31.41**	**30.6609**
cost ($/h)	**32653.32**	**32704.45**	**32732.95**	**32659.35**	**32731.96**	**32698.20**	**32762.12**	**32704.45**

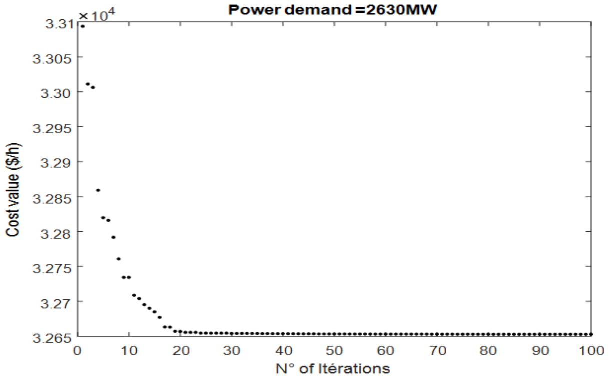

Fig.16. Convergence of fifteen generating unit system for P_D=2630 MW

Table 10 shows the summarized result of EDP for load demand of 1600MW, 2000MW, 2400 and 2800MW are obtained by the proposed EVOA algorithm with stopping criteria based on maximum-generation=100.

Table 9. Test results for 15-unit system

	Power demand(MW)			
Unit (MW)	**1600**	**2000**	**2400**	**2800**
P_1	192.4320	195.2382	352.4247	454.9241
P_2	192.5767	394.4830	356.3350	454.9734
P_3	129.9991	130	129.9847	130
P_4	130	130	130	130
P_5	150.0045	209.5171	332.3252	431.4531
P_6	191.1928	275.7624	406.5987	455.5447
P_7	371.4190	450.0090	465	465
P_8	60.0013	60.0104	60.0007	60.0013
P_9	25.0463	25	25.0111	25.0003
P_{10}	25.0043	25.0062	25.0043	64.9802
P_{11}	55.3374	20.1338	51.2433	54.4874
P_{12}	34.2634	46.9852	36.8985	59.1273
P_{13}	25.0127	25.0005	25.0001	25.0449
P_{14}	15.0881	15.0070	15.0377	15.0119
P_{15}	15.0234	15.0085	15.0276	15
Total output	**1612.4016**	**2017.1618**	**2425.8923**	**2840.5491**
Loss (MW)	**12.0161**	**17.1168**	**25.58237**	**40.2312**
cost ($/h)	**21770.4901**	**25924.4458**	**30155.9998**	**34488.3013**
T (S)	**11.572**	**12.532**	**13.354**	**14.400**

Variations of fuel cost in terms of number of iterations with EVOA for power demand of 1600MW, 2000MW,2400 and 2800MW are plotted in figure 17, figure 18, figure 19 and figure 20,the proposed EVOA reduces the cost of electrical power generate.

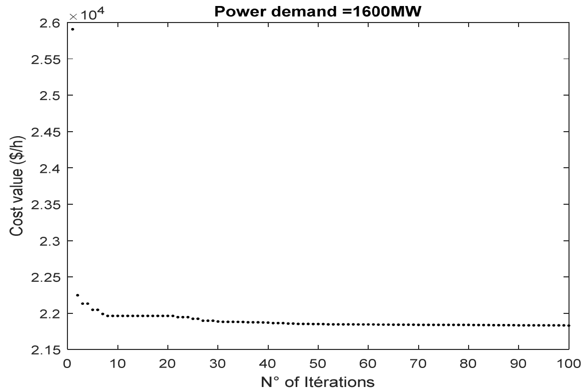

Fig. 17. Convergence of fifteen generating unit system for P_D=1600 MW

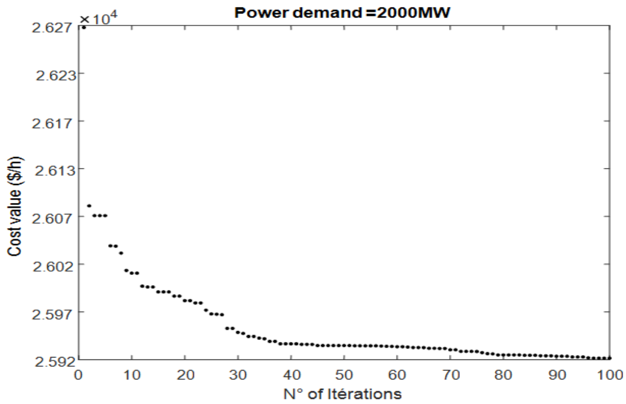

Fig.18. Convergence of fifteen generating unit system for P_D=2000 MW

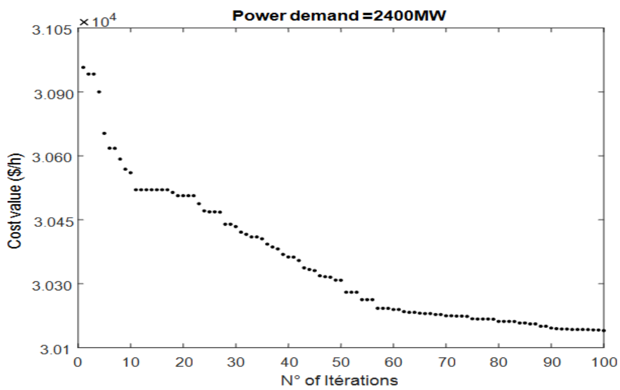

Fig. 19. Convergence of fifteen generating unit system for P_D=2400 MW

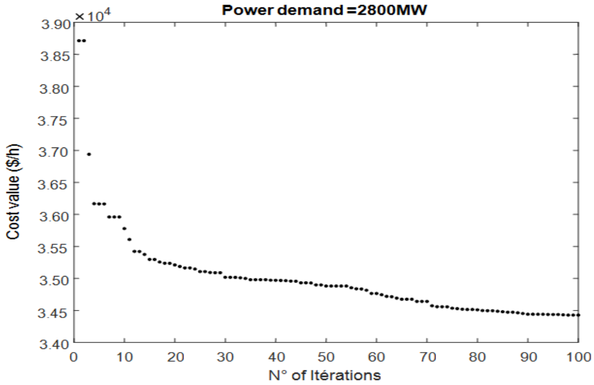

Fig.20. Convergence of fifteen generating unit system for P_D=2800 MW

The EVOA has therefore well given satisfactory results. This demonstrates that it is much faster and more efficient than similar techniques in dealing with the problems of objective optimization.

Application 4:

The application of the EVOA has been made on an IEEE network of fifteen generators of production; which possess a cost function to this production. The parameters related by the system composed of forty- units are indicated in the table 10.

Table 10.Generating unit data for 40-unit system

Unit	P_{ig}^{min}	P_{ig}^{max}	a_i($/MW^2)	b_i($/MW)	c_i ($)
1	36	114	0.00690	6.73	94.705
2	36	114	0.00690	6.73	94.705
3	60	120	0.02028	7.07	309.540
4	80	190	0.00942	8.18	369.030
5	47	97	0.01140	5.35	148.890
6	68	140	0.01142	8.05	222.330
7	110	300	0.00357	8.03	287.710
8	135	300	0.00492	6.99	391.980
9	135	300	0.00573	6.60	455.760
10	130	300	0.00605	12.9	722.820
11	94	375	0.00515	12.9	635.200
12	94	375	0.00569	12.8	654.690
13	125	500	0.00421	12.5	913.400
14	125	500	0.00752	8.84	1760.40
15	125	500	0.00752	8.84	1760.40
16	125	500	0.00752	8.84	1760.40
17	220	500	0.00313	7.97	647.850
18	220	500	0.00313	7.95	649.690
19	242	550	0.00313	7.97	647.830
20	242	550	0.00313	7.97	647.810
21	254	550	0.00298	6.63	785.960
22	254	550	0.00298	6.63	785.960
23	254	550	0.00284	6.66	794.530
24	254	550	0.00284	6.66	794.530
25	254	550	0.00277	7.10	801.320
26	254	550	0.00277	7.10	801.320
27	10	150	0.52124	3.33	1055.10
28	10	150	0.52124	3.33	1055.10
29	10	150	0.52124	3.33	1055.10
30	47	97	0.01140	5.35	148.890
31	60	190	0.00160	6.43	222.920
32	60	190	0.00160	6.43	222.920
33	60	190	0.00160	6.43	222.920
34	90	200	0.00010	8.95	107.870
35	90	200	0.00010	8.62	116.580
36	90	200	0.00010	8.62	116.580
37	25	110	0.01610	5.88	307.450
38	25	110	0.01610	5.88	307.450
39	25	110	0.01610	5.88	307.450
40	242	550	0.00313	7.97	647.830

Table 11 present an optimum simulation results of EVOA EDP compared with simulation results of *SOA* , *OHS* , *HBB–BC* , *FAPSO-NM* , *DE* ,ABC and TLBO where the charge is modified as follows: P_D=10500MW.The results obtained by EVOA are satisfactory when compared with other processes figure 21.

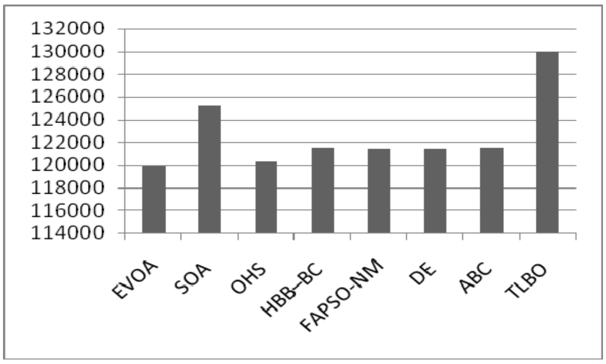

Fig.21. Illustration of *EDP* by EVOA and other processes in application 4

Variations of fuel cost in terms of number of iterations with EVOA for power demand of 10500MW are plotted in figure 22 the proposed EVOA reduces the cost of electrical power generate.

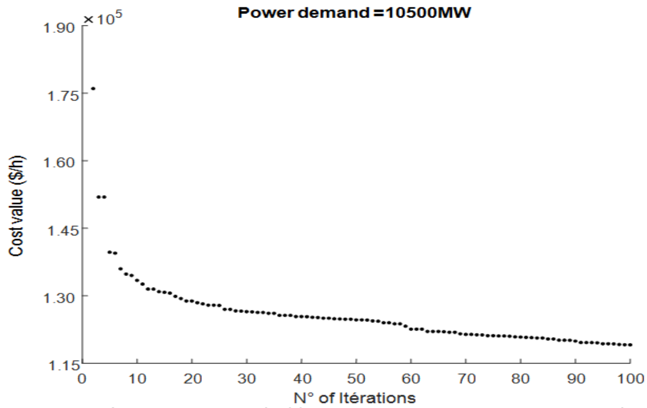

Fig. 22. Convergence of fifteen generating unit system for P_D=10500 MW

- The simplified generalized term taken in this paper distinctly confers optimal generation scheduling of thermal units for the determined charge request without necessity of repeated steps. As a consequence, the counting of the total generation cost will be an easier task.
- The suggested procedure needs a less number of repetitions for convergence after including transmission losses in the economic power dispatch problem.
- The suggested EVOA procedure can be realized for large-scale systems.
- The suggested procedure gives the optimal solution with less computational effort.

Conclusions

The aim of this economic dispatch paper is to present the proposed EVOA and compare it with different methods to analyze power systems to get the best economic benefit while minimizing cost and losses.

Egyptian Vulture Optimization Algorithm (EVOA), is a new optimization suggested by this paper in the domain of Economic Dispatch. So as to show the efficiency of EVOA using three, six and fifteen generating units test systems.

Table 11 Economic dispatch results for 40-unit system

Unit (MW)	*Proposed* EVOA	SOA [60]	OHS [61]	HBB–BC [44]	FAPSO-NM[62]	DE [63]	ABC [42]	TLBO [64]
P_1	113.7472	93.298	103.9422	114.00	111.38	110.8256	-	36.1161
P_2	112.3622	93.298	112.2758	114.00	110.93	111.1008	-	37.9455
P_3	97.99708	99.298	97.2549	97.4243	97.41	97.3996	-	61.8403
P_4	190	169.298	179.8187	179.7324	179.33	179.7336	-	93.4369
P_5	94.7311	76.298	95.0966	88.6784	89.22	92.2835	-	83.3052
P_6	13.7627	119.298	139.5940	140.00	140	140.0000	-	120.2602
P_7	299.2518	279.298	263.8120	300.00	259.62	259.6004	-	290.4140
P_8	299.1143	279.298	293.0950	284.5997	284.66	284.6014	284.5962	200.0000
P_9	300	279.298	299.5109	284.5737	284.66	284.6000	284.5294	293.7905
P_{10}	233.3090	279.298	130.8497	130.00	130	130.0000	130.0033	210.5287
P_{11}	213.4865	94	102.1717	94.00	168.82	168.7999	168.7903	337.4764
P_{12}	94.0150	354.298	95.9356	94.00	168.82	168.8004	94.0010	249.7551
P_{13}	129.4968	125	129.7004	214.7623	214.75	214.7597	215.4183	380.7705
P_{14}	293.0991	302.286	384.2587	304.5196	394.28	394.2796	394.2843	125.2402
P_{15}	309.9737	479.298	301.7727	394.2794	304.54	394.2793	394.2274	487.4984
P_{16}	317.1110	264.182	301.7773	394.2794	394.3	304.5195	394.1741	500.0000
P_{17}	494.8552	479.298	496.6855	489.2795	489.29	489.2796	489.2802	319.7599
P_{18}	499.9629	479.298	490.4517	489.2795	489.29	489.2793	489.2863	237.2392
P_{19}	550	529,298	502.7192	511.2845	511.28	511.2798	511.2606	516.5296
P_{20}	550	529.298	510.7183	511.2845	511.29	511.2796	511.2471	524.5736
P_{21}	548.2387	529.298	523.3236	523.2196	523.33	523.2793	523.3126	540.1990
P_{22}	550	529.298	524.7491	523.2196	523.48	523.2795	523.2619	549.3921
P_{23}	550	529.298	523.4055	523.2196	523.33	523.2800	523.2069	550.0000
P_{24}	550	529.298	522.6936	523.2196	523.33	523.2796	523.2790	522.9545
P_{25}	550	529.298	522.6783	523.2196	523.33	523.2795	523.2828	532.1005
P_{26}	550	529.298	538.1215	523.2196	523.33	523.2797	523.2828	542.7990
P_{27}	11.0938	10	149.7369	10.00	10	10.0000	10.0035	56.7790
P_{28}	11.4952	10	131.3113	10.00	10	10.0000	10.0601	23.8696
P_{29}	10.1714	10	130.7194	10.00	10	10.0000	10.0063	12.7165
P_{30}	96.8730	47	92.7962	89.3218	88.7	87.8823	88.0050	86.0264
P_{31}	189.8849	169.298	185.4022	190.00	190	190.0000	189.8676	190.0000
P_{32}	190	169.298	174.0935	190.00	190	190.0000	189.9970	190.0000
P_{33}	189.9577	169.298	168.3946	190.00	190	190.0000	179.4734	190.0000
P_{34}	199.9353	179.298	176.0944	200.00	165	164.8000	164.8527	192.4549
P_{35}	200	179.298	104.4641	200.00	166	164.8422	164.8280	189.1622
P_{36}	199,9816	179.298	167.3644	200.00	165	164.8171	164.8093	195.0759
P_{37}	109,9799	89.298	89.9918	110.00	110	110.0000	109.9733	109.6457
P_{38}	110	89.298	102.7658	110.00	110	110.0000	109.9999	110.0000
P_{39}	109.1052	89.298	108.1541	110.00	110	110.0000	109.9544	109.3120
P_{40}	242.0085	529.298	532.2987	511.2845	511.3	511.2794	511.2777	501.2304
Total output	**10500.00**	**10500**	**10500**	**10499.90**	**10500**	**10500**	**-**	**10500,198**
cost ($/h)	**119923.6629**	**125248.11**	**120240**	**121471.72**	**121418.3**	**121414.937**	**121479.6467**	**129960.0**

The method of Egyptian Vulture Optimization Algorithm, is included for the first time in Economic Dispatch, we obtained very satisfactory results (cost, P_L) compared with results of previous studies relied on other methods .As GA, EP,EP-SQP,PSO,PSO-SQP, GAB, GAF, CEP, FEP, MFEP,IFEP, GAB, PS, GSA, ABC, HHB-BC, NPSO-LRS,BFO, NAPSO, SOH-PSO, HHS, GA, BB-BC, IPSO,IPSO-TVAC, BSA, PSO , GAAPI , SOH-PSO, PSO , APSO , TS and SA.

EVOA is the most effective methods, easy to applied and able to search near total optimum solutions, the advantage of the EVOA method is its ability in finding high quality solutions reliably with fast convergence characteristics. It will give the same optimal solution for different experiments and it can be easily implemented for the system consisting of a greater number of generating units. So, this result proves that EVOA optimization is a reliable technique for solving Economic Dispatch problem.

APPENDIX

B Loss coefficients matrix for six-unit system

$$B_{ij} = \begin{bmatrix} 0.0017 & 0.0012 & 0.0007 & -0.0001 & -0.0005 & -0.0002 \\ 0.0012 & 0.0014 & 0.0009 & 0.0001 & -0.0006 & -0.0001 \\ 0.0007 & 0.0009 & 0.0031 & 0.000 & -0.0010 & -0.0006 \\ -0.0001 & 0.0001 & 0.0000 & 0.0024 & -0.0006 & -0.0008 \\ -0.0005 & -0.0006 & -0.0010 & -0.0006 & 0.0129 & -0.0002 \\ -0.0002 & -0.0001 & -0.0006 & -0.0008 & -0.0002 & 0.0150 \end{bmatrix}$$

B Loss coefficients matrix for fifteen-unit system

B_{ij}=1e-5

$$\begin{bmatrix}
1.4 & 1.2 & 0.7 & -0.1 & -0.3 & -0.1 & -0.1 & -0.1 & -0.3 & 0.5 & -0.3 & -0.2 & 0.4 & 0.3 & -0.1 \\
1.2 & 1.5 & 1.3 & 0.0 & -0.5 & -0.2 & 0.0 & 0.1 & -0.2 & -0.4 & -0.4 & -0.0 & 0.4 & 1.0 & -0.2 \\
0.7 & 1.3 & 7.6 & -0.1 & -1.3 & -0.9 & -0.1 & 0.0 & -0.8 & -1.2 & -1.7 & -0.0 & -2.6 & 11.1 & -2.8 \\
-0.1 & 0.0 & -0.1 & 3.4 & 0.7 & -0.4 & 1.1 & 5.0 & 2.9 & 3.2 & -1.1 & -0.0 & 0.1 & 0.1 & -2.6 \\
-0.3 & -0.5 & -1.3 & -0.7 & 9.0 & 1.4 & -0.3 & -1.2 & -1.0 & -1.3 & 0.7 & 0.2 & 0.2 & 2.4 & -0.3 \\
-0.1 & -0.2 & -0.9 & -0.4 & 1.4 & 1.6 & -0.0 & -0.6 & -0.5 & -0.8 & 1.1 & -0.1 & -0.2 & -1.7 & 0.3 \\
-0.1 & 0.0 & -0.1 & 1.1 & -0.3 & -0.0 & 1.5 & 1.7 & 1.5 & 0.9 & -0.5 & 0.7 & -0.0 & -0.2 & -0.8 \\
-0.1 & 0.1 & 0.0 & 5.0 & -1.2 & -0.6 & 1.7 & 16.8 & 8.2 & 7.9 & -2.3 & -3.6 & 0.1 & 0.5 & -7.8 \\
-0.3 & 0.2 & -0.8 & 2.9 & -1.0 & -0.5 & 1.5 & 8.2 & 12.9 & 11.6 & -2.1 & -2.5 & 0.7 & -1.2 & -7.2 \\
-0.5 & -0.4 & -1.2 & 3.2 & -1.3 & -0.8 & 0.9 & 7.9 & 11.6 & 20.0 & -2.7 & -3.4 & 0.9 & -1.1 & -8.8 \\
-0.3 & -0.4 & -1.7 & -1.1 & 0.7 & 1.1 & -0.5 & -2.3 & -2.1 & -2.7 & 14.0 & 0.1 & 0.4 & -3.8 & 16.8 \\
-0.2 & -0.0 & -0.0 & -0.0 & -0.2 & -0.1 & 0.7 & -3.6 & -2.5 & -3.4 & 0.1 & 5.4 & -0.1 & -0.4 & 2.8 \\
0.4 & 0.4 & -2.6 & 0.1 & -0.2 & -0.2 & -0.0 & 0.1 & 0.7 & 0.9 & 0.4 & -0.1 & -10.3 & -10.1 & 2.8 \\
0.3 & 1.0 & 11.1 & 0.1 & -2.4 & -1.7 & -0.2 & 0.5 & -1.2 & -1.1 & -3.8 & -0.4 & -10.1 & 57.8 & -9.4 \\
-0.1 & -0.2 & -2.8 & -2.6 & -0.3 & 0.3 & -0.8 & -7.8 & -7.2 & -8.8 & 16.8 & 2.8 & 2.8 & -9.4 & 128.3
\end{bmatrix}$$

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