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A Novel Approach for Optimization of Z-Matrix Building Process Using Ant Colony Algorithm

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ABSTRACT

In this paper, a novel approach for Z-matrix building process is proposed. The proposed algorithm is based on Ant Colony optimization technique. This algorithm has been tested on IEEE 14 bus benchmark and the results are compared with a Genetic Algorithm (GA) based optimization. According to simulation results, it is proved that using the Ant Colony based algorithm, the number of iterations required for convergence and consequently the time needed for Z matrix building process are considerably less.

KEY WORDS: Z-matrix building, Ant Colony optimization, GA optimization

1. INTRODUCTION

The three phase impedance matrix (Z matrix) is important because in comparison to the admittance matrix, it presents more information about the grid [1]. Unlike the admittance matrix, the Z-matrix is not sparse. The diagonal elements of this matrix describe the thevenin impedance seen from each of the grid buses [2].

Due to the importance of this matrix in power grid analysis, there have been many papers in the literature regarding the Z-matrix building algorithms for large-scale power systems. In [3], using two primary matrices which are built from the topological characteristics of the distribution networks, a robust and accurate approach for Z-matrix building is proposed which improves the power flow solutions. One effective approach for construction of Z-matrix is decomposition. In [4], using a simple search technique with the two matrices proposed in the paper, the decomposition approach for Z-matrix building is accomplished and it is proved that this approach is effective and universal. By utilization of bus voltage, bus current injection and branch current and employing back-forward method of flow calculating in radiate networks, a new viewpoint of Z-matrix construction is proposed in [5]. Furthermore, in [6], a generalized algorithm for Z-bus matrix construction is proposed which incorporates optimal line ordering and shunt elements in the network. In order to reduce the calculation time of Z-matrix building in large scale power systems, a Genetic Algorithm (GA) based method is proposed in [7] for optimal elements selection.

Improving Z-matrix building process can be realized from the two following view points:

I- Minimizing the time required for this process.

II-Decreasing the amount of calculations and memory space needed to store the information during this process.

In this paper, improving the first purpose has been noticed. In other words, regardless of the required memory, the purpose is to minimize the time needed for Z-matrix building process.

2. Time evaluation criterion

One of the parameters that can be derived from any processor data sheet is the time required for performing a process. The time required to perform a mathematical operation in a processor depends on its internal structure. Namely, if a particular block in the processor structure has been specified for a given mathematical operator, the time needed to perform the process is limited to the number of clock pulses required for this block operation. Otherwise, this operator is implemented by the present blocks of the processor based on a special logic. In this condition, the number of clock pulses needed to achieve an operator is increased considerably. As an example, the number of clock pulses needed for summation, subtraction, multiplication and division operators for a typical two core Pentium processor is listed in Table 1.

Table. 1 Number of Clock Pulses Required for Mathematical Operations in a Typical Processor

Operator	Command	Number of clock pulses
Summation	FADD	1-7
Subtraction	FSUB	1-7
Multiplication	FMUL	1-7
Division	FDIV	39-42

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As seen in the table, the number of clock pulses needed for division is considerably more than other operations which implies that there is not a specific block for division in the processor structure and this operation is achieved by means of other operators.

3. MATCHING THE Z-MATRIX BUILDING TO TRAVELING SALESMAN PROBLEM (TSP)

The Traveling Salesman Problem (TSP) is to find the shortest path visiting each of a given set of cities and returning to the starting point. If we consider each line of the grid as a city, the Z-matrix building process would be expressed in the form of a TSP as following:

" The supposed viewer is going to minimize the time (path) required for traveling from a line (city) to another line (city) and entering (visiting) all the lines (cities) into the matrix."

According to the above definition, the following points are important:

I. The difference between Z-matrix building process with the main TSP is that the supposed viewer is not limited to return to the starting line (city).

II. The required time for entering the next line in each step is defined based on the processor parameters and is considered as the distance between two cities.

III. The distance between cities should be calculated dynamically. This is due to the fact that the grid graph is changed in each step and so the required time for entering the next line depends on the status of the grid graph at the last step.

For explaining this problem, Figure 1 is presented that represents a part of a typical grid.

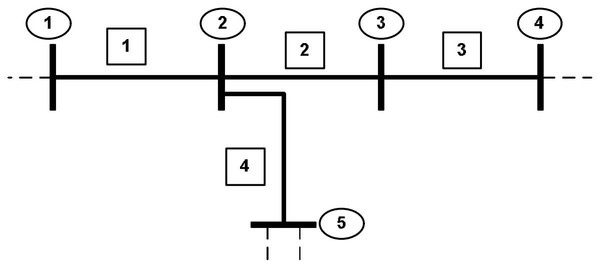

Fig. 1 A part of a typical grid

For entering the line 2 in Figure 1, we will consider two cases:

I. Both of the lines 3 and 1 have been entered to the grid. This means that entering the line 2 follows the 4th case of the classic technique of Z-matrix building explained in [8] and includes a set of calculations.

II. Only line 3 or only line 1 has been entered to the grid. Here, entering the line 2 corresponds to entering a new bus to the grid and hence adding a column and a row to the last status of the grid matrix and no calculation will be needed.

It is obvious that the required time for these two cases depends on the amount of calculations and will be different. In TSP form expression, this corresponds to the change of the distance between two lines (cities) based on the last status of the grid graph.

4. **Specifying the required time for entering the lines**

For convenience, the required time for accessing to the information or storing them in the memory which depends to the type of the processor will be considered in the form of a parameter called T_{rep} .

- T_{rep} : The time needed for replacement
- T_{sub} : The required time for subtraction
- T_{add} : The required time for summation
- T_{div} : The required time for division
- T_{mul} : The required time for multiplication

Based on the above definitions, the required time for each of the four cases of the classic technique of Z-matrix building explained in [8], is calculated as following:

I. Adding a line between a new bus and the reference bus:

$$T = (n+1)^2 T_{rep} \quad (1)$$

II. Adding a line between a new bus and a present bus:

$$T = (n+1)^2 T_{rep} + T_{add} \quad (2)$$

III. Adding a line between a present bus and the reference bus:

$$T = (n+1)^2 T_{rep} + T_{add} + n^2 (T_{mul} + T_{div} + T_{sub}) \quad (3)$$

IV. Adding a line between two present buses:

$$T = (n+1)^2 T_{rep} + 2T_{add} + T_{mul} + (2n+1)T_{sub} + n^2 (T_{mul} + T_{div} + T_{sub}) \quad (4)$$

5. Differences between the simulations using ga [7] and the proposed ant colony optimization technique

I. In [7], as a constraint, the buses connected to the reference bus, which are mainly buses connected to the power plants, are entered to the impedance matrix at the first step. In the simulations based on Ant Colony optimization technique, this constraint is not taken into account. The results also show that this constraint will cause to get away from the optimized point.

II. The given expression for the required time for the 3rd case of the classic technique in [7] is irrational due to the dimension of the right hand side of this equation that is the square of the time unit. This expression is as following:

$$T = T_a + \underline{\underline{T_d\,(n+n^2)\,T_M}} + n^2 T_m + n^2 T_R \quad (5)$$

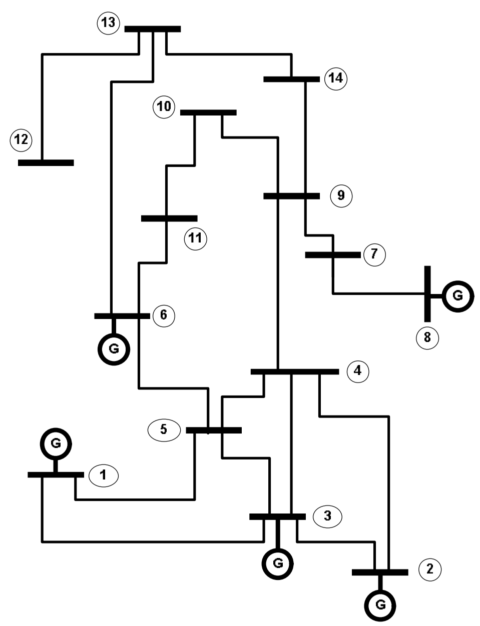

Fig. 2 IEEE 14 bus benchmark

Table. 2 Numbering of the IEEE 14 Bus Benchmark

Element Number	From bus	To bus
1	0	1
2	0	8
3	0	2
4	0	3
5	0	6
6	1	5
7	1	2
8	2	3
9	2	5
10	2	4
11	3	4
12	4	7
13	4	9
14	2	5
15	5	6
16	6	11
17	6	12
18	6	13
19	7	8
20	7	9
21	9	14
22	9	10
23	10	11
24	12	13
25	13	14

As defined in [7], T_a , T_d, T_M, T_m and T_R are the time needed for addition, division, multiplication, subtraction and replacement respectively. As obvious in (5), the parameters T_d and T_M are multiplied and so the result dimension will be the square of the time unit while the dimension of the left hand side of (5) is the time unit.

In [7], the time needed for attaining the optimized path is neglected in comparison to the required time for Z-matrix building process. This is irrational especially when the number of the buses increases.

6. SIMULATION RESULTS

In this paper, the proposed method is based on the Ant Colony algorithm [9]. To compare the Genetic and Ant Colony algorithms, the results of analyzing on the 14 bus benchmark is presented. This benchmark is illustrated in Figure 2. It should be mentioned that for comparison, the numbering presented in [7] is used which is given in Table 2 and the results of testing the proposed Ant Colony algorithm on the IEEE 57 bus benchmark are presented in Table 3.

As seen in the table, the number of clock pulses needed for division is considerably more than other operations which implies that there is not a specific block for division in the processor structure and this operation is achieved by means of other operators.

7. **Comparison between the proposed ant colony based algorithm simulation results and the results of the ga based algorithm in [7]**

As seen in table II, unlike the mentioned constraint, for entering the buses connected to the reference bus at the first step of Z-matrix building process, the bus number 6 through the impedance 5 (according to Figure 2 and table 1) in the 11th step and the bus number 3 through the impedance 4 (according to Figure 2 and table 1) in the 16th step have been entered to the grid impedance matrix.

I. **Rapidity**: One of the prominences of the GA is the multilateral search and operating on a collection of variables at the same time. In comparison to GA the Ant Colony Algorithm is considered as a sectarian algorithm. Consequently, if the number of the grid buses and so the number of the grid lines increases; the deceleration rate of the Ant Colony algorithm would be more considerably.

Based on the experiences on TSP solving, if the number of the cities becomes more than 30, then in comparison to GA, the required time for solving the TSP using Ant Colony algorithm would be considerable.

II. **Accuracy**: Especially when the initial population is low, if a chromosome with a higher value in comparison to others is present in the initial population, the GA would be converged to the local optimized points while this is considered as an advantage for the Ant Colony algorithm.

III. **The required number of iterations for convergence**: For comparison, two diagrams are represented in Figure 3. As seen, for the IEEE 14 bus benchmark, the number of iterations required for convergence in the Ant Colony algorithm is considerably less.

Table. 3 Results of Testing the proposed Ant Colony based algorithm on IEEE 57 bus benchmark

Element Number	From bus	to bus	result from ACO
1	0	1	5
2	0	2	18
3	0	5	32
4	0	11	20
5	0	13	61
6	1	2	21
7	2	3	30
8	3	4	29
9	4	5	19
10	4	6	75
11	6	7	16
12	6	8	23
13	8	9	27
14	9	10	3
15	9	11	7
16	9	12	68
17	9	13	6
18	13	14	14
19	13	15	28
20	1	15	1
21	1	16	74
22	1	17	4
23	3	15	17
24	4	18	22
25	5	6	67
26	7	8	59
27	10	12	31
28	11	13	15
29	12	13	83
30	12	16	62
31	12	17	66
32	14	15	58
33	18	19	2
34	19	20	8
35	21	20	25
36	21	22	24
37	22	23	65
38	23	24	12
39	24	25	13
40	24	26	69
41	26	27	78
42	27	28	77
43	28	29	57
44	7	29	10
45	25	30	76
46	30	31	9
47	31	32	11
48	32	33	64
49	34	32	55
50	34	35	26
51	35	36	73
52	36	37	63
53	37	38	72
54	37	39	71
55	36	40	81
56	22	38	33
57	11	41	82
58	41	42	44
59	41	43	80
60	38	44	52
61	15	45	60
62	14	46	54
63	46	47	53
64	47	48	70
65	48	49	51
66	49	50	43
67	50	51	79
68	10	51	56
69	13	49	37
70	29	52	34
71	52	53	36
72	53	54	35
73	54	55	50
74	11	43	49
75	44	45	48
76	40	56	38
77	56	41	39
78	56	42	45
79	39	57	40
80	57	56	46
81	38	49	47
82	38	48	42
83	9	55	41

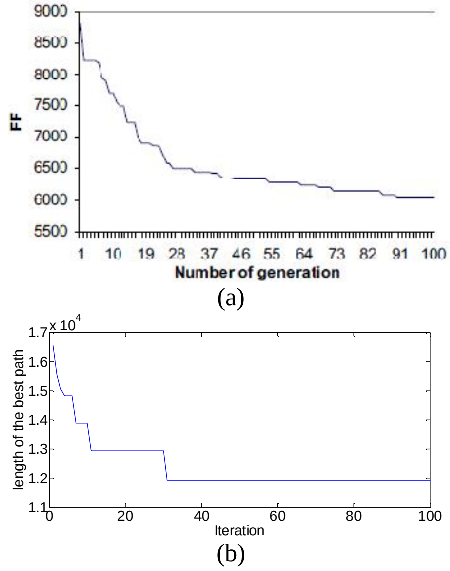

Fig. 3 The length of the best path versus the iterations number. (a) GA [7], (b) Ant Colony

8.CONCLUSION

In this paper, a new approach for Z-matrix building process is proposed. This method is based on the Ant Colony optimization technique. The proposed technique is tested on the IEEE 14 bus benchmark and the results are compared with a GA based algorithm for Z-matrix building. The results prove that using the proposed Ant Colony based algorithm, the number of iterations needed for the convergence and as a result, the time required for Z-matrix building process is considerably less in comparison with the GA based method. Finally, the proposed method is tested on the IEEE 57 bus benchmark and the results are presented.

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