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Optimal Reconfiguration of Power Distribution Systems Based on Symbiotic Organism Search Algorithm

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Abstract

This paper presents a reconfiguration of electric power distribution network based on the symbiotic organism search algorithm (SOS). The goal here is to come out with an optimal reconfiguration of a power distribution network that minimises the active power losses for a good power flow. This method is applied to IEEE 33 bus and the results show a significant reduction of active power losses. The execution time for this algorithm is found to be smaller compared to other metaheuristic algorithms.

Keywords

Reconfiguration, Algorithm of Symbiotic Search, Metaheuristic Algorithm

1. Introduction

The growth of the demand of electrical energy is of a great challenge for the entire society. This calls for optimization of the production, the distribution and the use of electrical energy. The extension of a distribution power network being difficult and costly, it is necessary to optimize the management of the energy in order to ensure the satisfaction of customers, reduce the production cost and increase the income.

There are several technics of optimization of power distribution network. Ahmed Ould Nagi [1] proposed an optimization of power flow in a network using the pareto approach based on genetic algorithm reconfiguration of a network based on the PGSA algorithm (plant growth simulation algorithm). The results obtained with an IEEE 33-bus are presented. M.A. Kashem *et al.* [3] propose an algorithm that determines the power losses for the different combinations of switches. Bogdan Tomoiaga *et al.* [4] propose an optimal reconfiguration of power distribution network based on genetic algorithm using the flexibility and robustness. Juan Li [5] proposed an algorithm based on graph theory applied on a network of 200 buses that minimize active and reactive losses during power flow. Francisco Rivas Davalos [6] presented a reconfiguration of power distribution network based on genetic algorithm. P. Subburaj *et al.* [7] propose a genetic algorithm applied to a 16 buses. It minimizes significantly power losses. This paper presents an approach of minimization of losses using symbiotic organism search algorithm (SOS) to optimize the reconfiguration of the power distribution network. The decision variables are tied to the state of switches. We use the binary code 0 (OFF) and 1 (ON) different from Gomes, F. V., *et al.* [8] who use continuous functions. We apply this algorithm on IEEE 33 bus.

2. Problem Statement

Let consider a simple linear network represented bellow **Figure 1**.

The objective is to minimize the joule losses by a proper reconfiguration of the network. The objective function is therefore:

$$\min f = \min\left(P_{t,loss}\right) \tag{1}$$

with $P_{t,loss}$, total active losses.

The apparent power carried by a branch, must be less than the maximal apparent power that branch can accept. The amplitude on a nod should be in the accepted range.

These constraints are express by:

$$S_i \le S_{i,\max} \tag{2}$$

$$V_{i,\min} \le V_i \le V_{i,\max} \tag{3}$$

The following equations enable us to calculate the power flow.

$$P_{i+1} = P_i - r_i \frac{P_i^2 + Q_i^2}{V_i^2} - P_{Li+1} \tag{4}$$

$$Q_{i+1} = Q_i - x_i \frac{P_i^2 + Q_i^2}{V_i^2} - Q_{Li+1} \tag{5}$$

$$P_{i+1} = P_i - r_i \frac{P_i^2 + Q_i^2}{V_i^2} - P_{Li+1} \tag{6}$$

$$V_{i+1}^2 = V_i^2 - 2\left(r_i P_i + x_i Q_i\right) + \left(r_i^2 + x_i^2\right)\frac{P_i^2 + Q_i^2}{V_i^2}$$

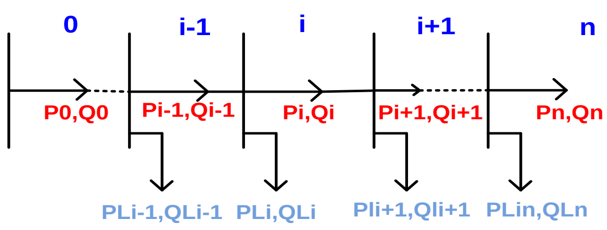

Figure 1. Simple network.

with:

P_i: active power on nod *i*.

Q_i: reactive power on node *i*.

$P_{i+1:}$ active power on nod $i + 1$.

$Q_{i+1:}$ reactive power on node $i + 1$.

r_i: resistance of branch *i*.

x_i: reactance of branch *i*.

V_i: real mean value of the voltage on node *i*.

V_{i+1}: real mean value of the voltage on node $i + 1$.

S_i: apparent power on node *i*.

The total losses are expressed by the relation:

$$P_{T,loss} = \sum_{i=0}^{n-1} \frac{P_i^2 + Q_i^2}{V_i^2} r_i \tag{7}$$

The goal of the reconfiguration being to minimize the active power losses during the power flow, the problem is stated as follow:

$$\min \sum_{i=0}^{n-1} \frac{P_i^2 + Q_i^2}{V_i^2} r_i \tag{8}$$

Equations (2) and (3) are the constraints.

The reconfiguration hold on the following rules:

- All the load must be fed if not at least most of them.
- The reconfiguration of the network should be radial.
- The network islinear.

If we consider a network of n switches we arrive at the following vector:

$$X = \left[x_0\ x_1\ x_2\ x_3\ x_4 \cdots x_{n-1}\right]$$

3. Symbiotic Organism Search Algorithm (SOS)

The symbiotic organism search algorithm is a new algorithm develop by [9]. It determine the optimal organism that minimizes an objective function. It is ruled by the flow chart **Figure 2**.

Mutualism is a social system between the members of a same Professional branch. It is a lasting and complementary relation between two groups of plants, animals or human being.

Commensalism is an association of different species living in such a way that one of them depends on the others without any ham.

Parasitism is linked to predation. In that system, two organisms live together, one feeding himself at the cost of the other.

The detailed flow chart of the symbiotic organism search algorithm is presented at **Figure 3**.

Description of the Algorithm

STEP 1:

Initialisation of the ecosystem

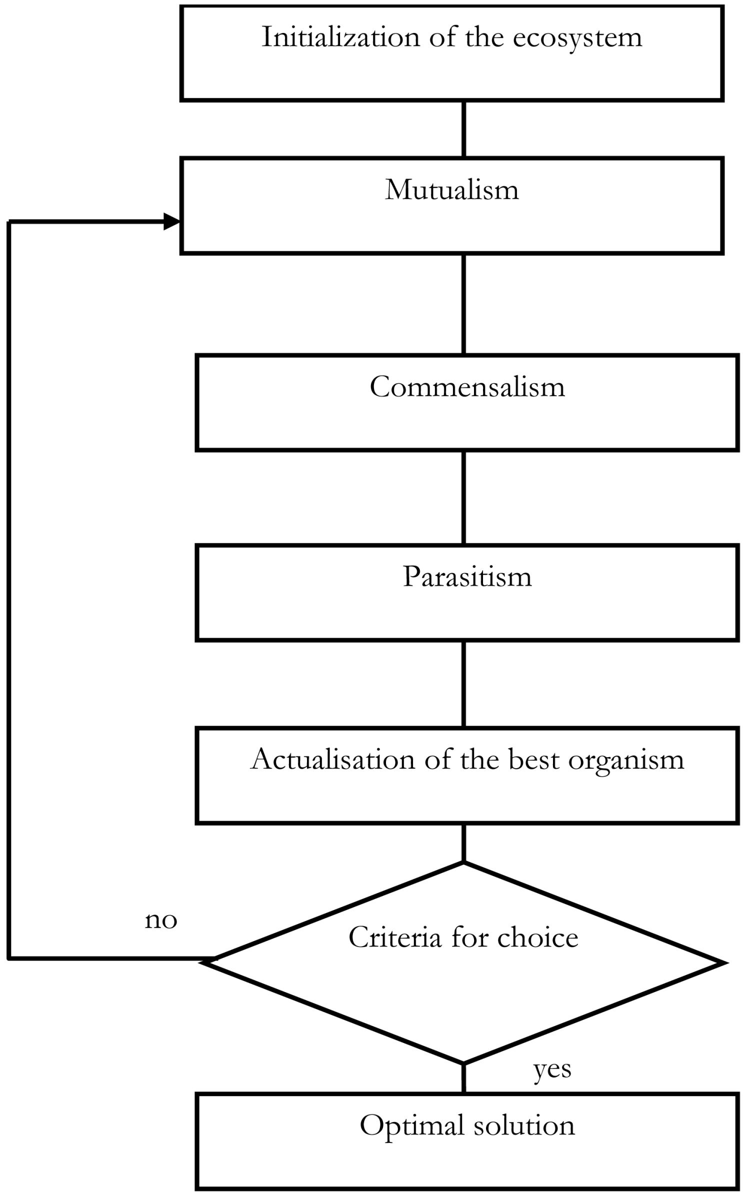

Figure 2. General flow chart for the symbiotic organism search algorithm.

At this level we determine the size of the ecosystem and the initial organism

STEP 2:

Phase de mutation phase

Ze select at random an organism X_j such that. $X_j \neq X_i$ Determine the mutual vector $(X_i + X_j)/2$. Determine two random number situated between 1 and 2. Modify the organisms X_i and X_j taking into account the mutual vector *Ze* obtain X_{in} and X_{jnov}. Calculate the value of the fitness function of each new organism and compare them.

STEP 3:

Phase of commensalism

STEP 4:

Phase of parasitism

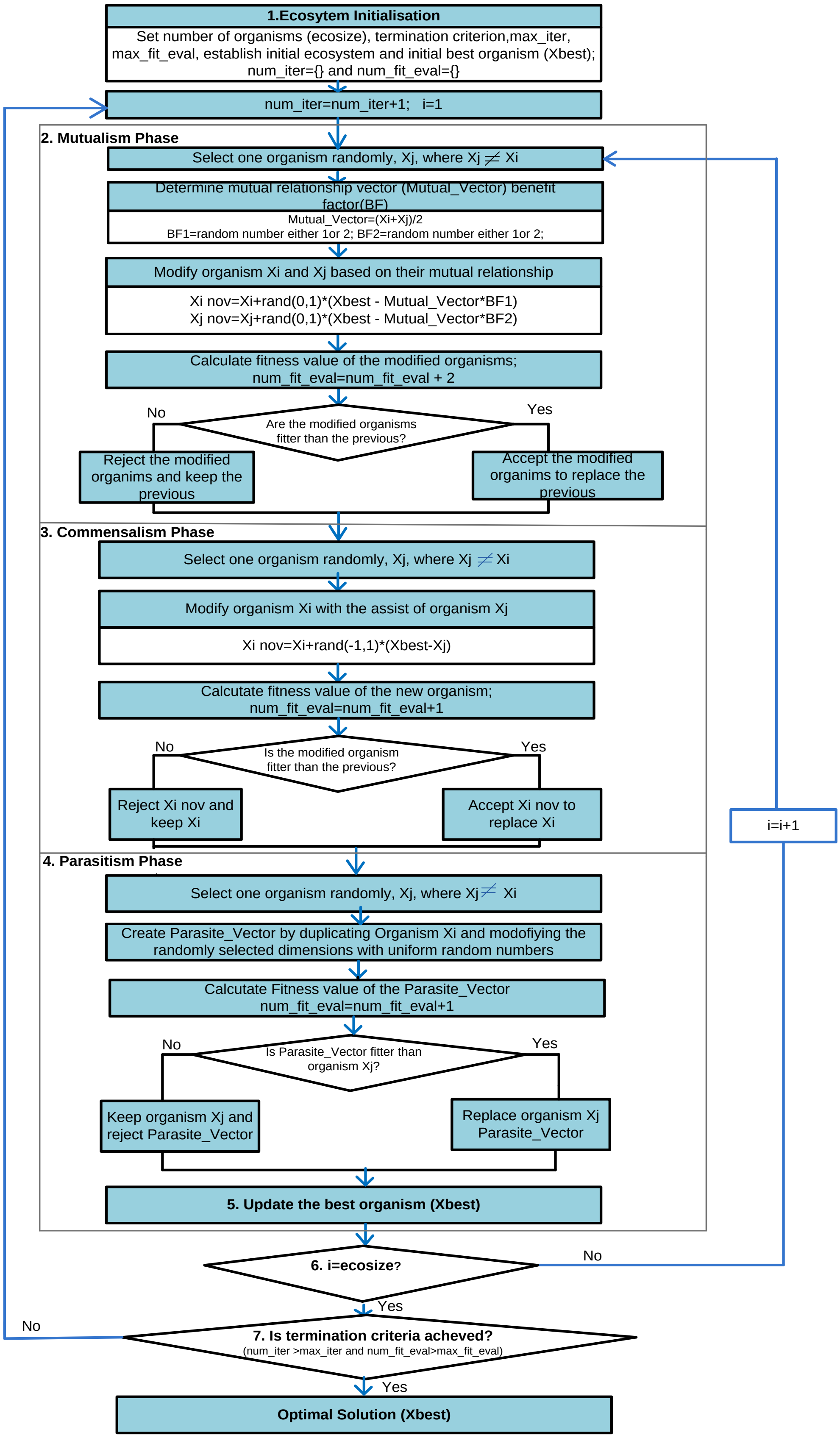

Figure 3. Detailed flow chart of the SOS algorithm [9].

4. Results and Discussion

The optimization code are written with Matlab. The characteristics of the computer used are: processor of 1.4 GHz, memory RAM of 2 Go, OS 64 bite WINDOWS 8.

The result obtained is a 37 elements line matrix. Each element correspond to the state of a switch between two nods. We start by calculating the total lose from the initial configuration. The optimization, give us the best organism witch correspond to the best configuration.

4.1. Presentation of the Structure

Figure 4 presents the IEEE 33 bus system.

Initially the state of the switches are: from S1 to S32 "ON" and S33, S35, S36, S37 "OFF".

The rMS of the voltage at nod 0 is 12.66 kV and the active power and reactive powers are respectively 3715 kW and 2300 kVAr.

4.2. Results

The characteristics of the network are found in Table 3. The goal is to calculate the active power loss in each branch and apply the optimization algorithm. The implementation is done in the Matlab environment

The initial binary code or organism is Figure 5.

From S1 to S31 "1" and from S32 to S37 "0".

1) The total loses are: 203,15 kW

The optimal organism which reduce the losses and enable the majority of customers to remain connected is Figure 6.

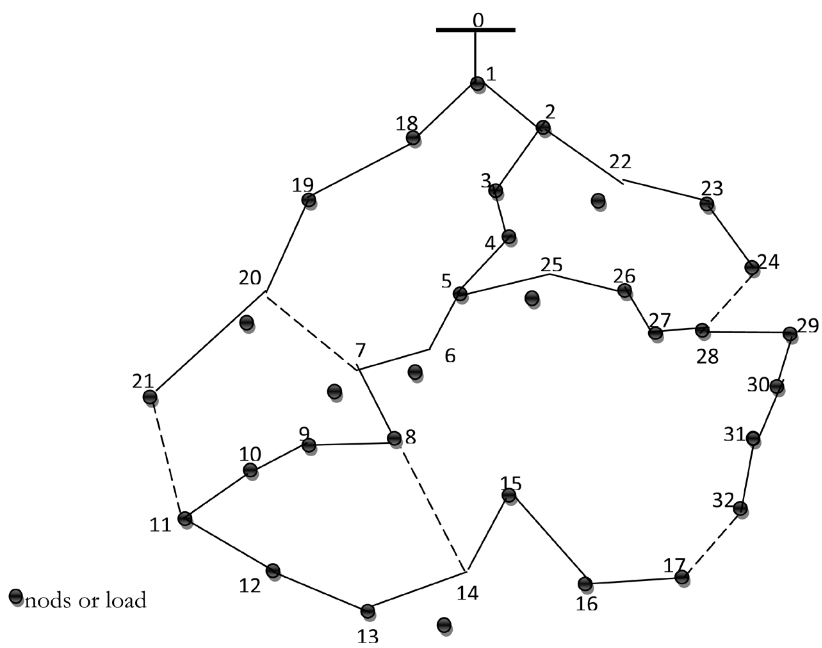

Figure 4. Presentation of the IEEE 33 nods network [2].

2) The total losses are: 175,3337 kW

The summary table is the following Table 1.

We obtain the following graph Figure 7.

Table 2 shows results obtained by the GA and SOS algorithm with the network characteristic of Table 3.

4.3. Discussion

Before the optimization, the open switches are S22, S23, S24, S30, S31, S32, S33, S34, S35, S37 the others are closed. This configuration allows for an active power loss of about 203.15 kW. After the implementation of the SOS algorithm the power loss is reduce to 175.3337 kW Table 1. Comparing with genetic algorithm Table 2, after simulations, we can see that the SOS algorithm is more effective

5. Conclusions

A novel approach based on symbiotic organism search algorithm has been implemented for the optimization of the distribution of electricity in a power network. The implementation was carried out on an IEEE 33 Bus system. The

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0

Figure 5. Initialorganism of IEEE 33 bus network.

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	1

Figure 6. Optimal Organism of the IEEE 33 bus network.

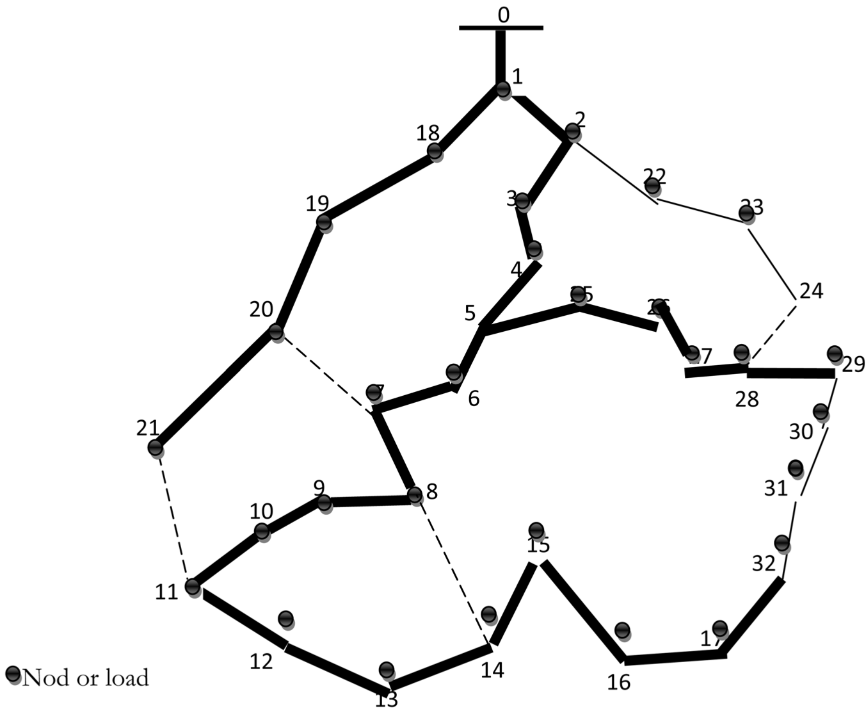

Figure 7. Optimal configuration by SOS algorithm for IEEE 33 nods network.

Table 1. Reconfiguration of the power network by SOS algorithm.

Before the reconfiguration			After the reconfiguration		
State of the switch		Total losses (kW)	State of the switch		Total losses (kW)
S32, S33, S34, S35, S36, S37	OFF	**203,15**	S22, S23, S24, S30,S31, S32, S33, S34, S35, S37	OFF	**175.3337**
De S1 à S31	ON		Other switches	ON	

Table 2. Comparative study between GA and SOS results.

Element	Initial state	GA	SOS
Open switch	S32, S33, S34, S35, S36, S37	S15, S25, SS31, S33, S34, S35	S22, S23, S24, S30,S31, S32, S33, S34, S35, S37
Losses (kW)	**203.15**	**194.6427**	**175,3337**
Number of itiration		**100**	**100**
Execution time (s)		**25.63080**	**0.259030**

Table 3. Caracteristics of the test network [2].

Bus to bus	Section resistance(Ω)	Section reactance(Ω)	End bus real load (kW)	End bus reactive load (kVAr)	Bus to bus	Section resistance(Ω)	Section reactance(Ω)	End bus real load (kW)	End bus reactive load (kVAr)	Bus to bus	Section resistance(Ω)	Section reactance(Ω)	End bus real load (kW)	End bus reactive load (kVAr)
0 - 1	0.0922	0.0470	100	60	13 - 14	0.5910	0.5260	60	10	25 - 26	0.2842	0.1447	60	25
1 - 2	0.4930	0.2511	90	40	14 - 15	0.7463	05450	60	20	26 - 27	1.0590	0.9337	60	20
2 - 3	0.3660	0.1864	120	80	15 - 16	0.2890	1.7210	90	20	27 - 28	0.8042	0.7006	120	70
3 - 4	0.3811	0.1941	60	30	16 - 17	0.7320	0.5740	90	40	28 - 29	0.5075	0.2585	200	600
4 - 5	0.8190	0.7070	60	20	1 - 18	0.1640	0.1565	90	40	29 - 30	0.9744	0.9630	150	70
5 - 6	0.1872	0.6188	200	100	18 - 19	1.5042	1.3554	90	40	30 - 31	0.3105	0.3619	210	100
6 - 7	0.7114	0.2351	200	100	19 - 20	0.4095	0.4784	90	40	31 - 32	0.3410	0.5302	60	40
7 - 8	1.0300	0.7400	60	20	20 - 21	0.7089	0.9373	90	40	7 - 20	2	2		
8 - 9	1.0440	0.7400	60	20	2 - 22	0.4512	0.3083	90	50	8 - 14	2	2		
9 - 10	0.1966	0.0650	45	30	22 - 23	0.8980	0.7091	420	200	11 - 21	2	2		
10 - 11	0.3744	0.1238	60	35	23 - 24	0.8960	0.7011	420	200	17 - 32	0.5	0.5		
11 - 12	1.4680	1.1550	60	35	5 - 25	0.2030	0.1034	60	25	24 - 28	0.5	0.5		
12 - 13	0.5416	0.7129	120	80										

simulations led to an optimal reconfiguration that minimizes the active power loss. The comparison of this algorithm with other metaheuristic algorithm such as GA, proves it superiority in losses reduction and short execution time.

In further work, we may consider combination of GA and SOS or another metaheuristic algorithm.

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Nomenclature

PGSA: Plant growth simulation algorithm
SOS: Symbiotic organism search algorithm
GA: Genetic algorithm