A NOVEL HYBRID ALGORITHM FOR RECONFIGURATION PROBLEM OF THE DISTRIBUTION NETWORKS

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ABSTRACT

One method of storing electrical energy in distribution networks is network reconfiguration. Reconfiguration in power systems can change the network topology and power flow with use of switches that can be closed and open. The main objective of the reconfiguration of distribution networks is reducing power losses and avoid network from overload. Reconfiguration is numerical optimization. Changes between open and close mode of switches should be done in such a way that the radial configuration remains radial. This study proposes a new optimization algorithm to solve the reconfiguration problem based on hybrid of particle swarm and Nelder-Mid(NM) optimization algorithms which is called PSO-NM. Simulation results on real network indicate that this new hybrid algorithm is more efficient and faster in comparsion with genetic algorithm.

1. INTRODUCTION

Distribution systems are typically designed as open ring and operate in a radial configuration. But protection system complexity and high short-circuit level do not let this happen. In recent years some progress has been made in processing technology that causes automation systems to be used in Distribution Company [1]. One of the most effective use of automation systems is their application in reconfiguration of distribution networks. Reconfiguration of distribution networks can reducing losses and avoid network from overload. Many methods used to optimize the reconfiguration problem in distribution networks. Authors in [2] uses the innovative research to find the best configuration. Artificial Intelligence in [3], GA in [4] and Simulated Annealing in [5] are the other methods used to optimize this important problem but these methods have poor convergency and heavy computational time in real networks.
The rest of this paper is arranged as follows. In section 2, the formulation of reconfiguration problem presented. The proposed algorithm use in this paper presented in Section 3. Section 4 presents real case study and discussed and conclusions are given in Section 5.

2. RECONFIGURATION PROBLEM

Reconfiguration problem is a Non-linear multi objective optimization problem. The objective function is minimizing the power losses and voltage drop and constraints are transformer load balancing, line flow limit and digression in feeder voltage from its reference value.

2.2. Objective function

Minimizing power losses are extracted from equation below

$$P_{loss} = \sum_{i=1}^{n_{br}} \mathrm{r_i} \frac{\mathrm{P_i}^2+Q_i^2}{\mathrm{V_i}^2} \quad (1)$$

$$X = [\mathrm{Tie}_1, Tie_2, \cdots Tie_{N,}, Sw_1, Sw_2, \cdots, Sw_N] \quad (2)$$

Where $\mathrm{P_i}$ and Q_i are active and reactive power in the lines. $\mathrm{r_i}$ and $\mathrm{V_i}$ are the resistance and voltage magnitude in *i*th branch. $\mathrm{N_{br}}$ Is the number of branches and X are the vector of control variables. T_{ie_i} is status of switch I, 0 for closed and 1 for opening switch. $\mathrm{S_w}$ shows which switch turn to the close and N_{tie} is the number of closed switches. For more understanding about X vector assumed that x can be reperesent as follow:

$$x = [1,0,0,1,0,15,4,19,22,39] \quad (3)$$

In this vector, X have 10 elements which the first five are binary numbers (0=open and 1=close) and the second five show the number of switches. In above vector switch 19, 4 and 39 are open (columns 2, 3 and 5 are zero).

2.2 Distribution lines constraints

The distribution lines constraints which are considered in system are as follows:

$$\left|\mathrm{P_{ij}^{Line}}\right| < \mathrm{p_{ij,max}^{Line}} \quad (4)$$

$$\mathrm{p_{ij}} = \sum_{i=1}^{N_{bus}} \mathrm{V_i V_j Y_{ij}} \cos(\theta_{ii} - \delta_i - \delta_j) \quad (5)$$

$$Q_{ij} = \sum_{k=0}^{N_{bus}} V_i V_j Y_{ij} \sin(\theta_{ii} \delta_i \delta_j) \quad (6)$$

P_{ij}^{Line} is power transmitted in distribution network and $p_{ij,max}^{Line}$ is the maximum power limit of the power flow in lines. P_i and Q_i are active and reactive power that injected to the *i*th buss. V_i and δ_i are amplitude and angle of voltage of *i*th buss. Y_{ij} and θ_{ij} are amplitude and angle of admittance of line between *i*th and *j*th buss, respectively.

2.3. Switching limitation

The maximum number of switching in any reconfiguration problem can express as fallow:

$$\sum_{i=1}^{N_s} |S_i - S_{oi}| \leq N_{switc\,h} \quad (7)$$

In this equation, S_i and S_{oi} are initiat state and new state of *i*th switches (0 means the switch is close and 1 shows open). N_s Is the maximum number of switches and N_{switch} Is the maximum number of switching [6].

2.4 buss voltage constraint

Each buss voltage should stay in limitation that can be shown as follow:

$$V_{min} \leq V_i \leq V_{max} \quad (8)$$

V_{min} and V_{max} are lower and upper limit of buss voltage, respectively.

2.5. Remaining radial configuration

The network after any reconfiguration process should be radial. The equation below ensures distribution networks remaining radial:

$M = N_{bus} - N_f$

Where M is the number of branches and N_{bus} and N_f Are respectively the number of nodes and resources.

1.6. Transformer constraint

$$|I_{i,j}| \leq I_{i,j}^{max} \quad (9)$$

$i = 1, 2, 3, \dots N_i$

In this constrain $I_{i,j}$ Is the amplitude of the transforms current and $I_{i,j}^{max}$ is the maximum current of *i*th transformer.

3 PROPOSED ALGORITHMS THAT USED IN HYBRID METHOD

For achieving the best algorithm for solving the reconfiguration problem combining the different methods is useful. In this section the algorithms that use in hybrid algorithm are explained.

3.1 Nelder-Mid algorithm

The aim of using this method is solving optimization problems without any constraints and derivative function.

3.2 PSO optimization algorithm

The particles are the basis of PSO algorithm. In each optimization they are trying to improve their position in the search apace.

3.3 Hybrid algorithm

In order to apply the hybrid algorithm into the problem of reconfiguration, the needed information in PSO-MN algorithm have to be defined, this information comprises branches impedance, Status of Switches and related parameters. The constraints of the problem can be transformed into an unconditional problem. This is done by using the following relation.

$$F(X) = f(x) - k_l\left(\sum_{j=1}^{N_{eq}} (h_j(x))^2\right) - k_2\left(\sum_{j=1}^{N_{ueq}} (Ma - g_j(x)]^2\right) \quad (10)$$

The objective function of reconfiguration problem is presented in equation (10). f(x) is the objective function of the reconfiguration problem (Power losses and Voltage drop). $h_j(x)$ and $g_j(x)$ are equality and inequality constraints respectively which comprise a series of limitations. N_{eq} and N_{ueq} are the number of equality and inequality constraints respectively. K_1 and K_2 ($K_1, K_2 > 0$) are penalty factors. These penalty factors should be as large as possible.

Equation below create the initial population:

$$population = \begin{cases} X_1 \\ X_2 \\ X_{3N+1} \end{cases} \quad (11)$$

$$X_{i=} [Tie_1 Tie_2 \dots, Tie_N, Sw_1, Sw_2, \dots Sw_n] \quad (12)$$

$i = 1, 2, \dots, 3N + 1$

By calculating the cost function for each member of the initial population, the losses computed and power flow done, then the initial population sort based on the objective function values from minimum to maximum.

By appling the MN algorithm to the first N+1 rows of initial sorted population and PSO to the other remaining 2N rows for PSO algorithm at last then the results from these algorithms combined. By reaching the maximum iteration the simulation process ends otherwise another population generate and feed into algorithm. The Hybrid ahgorithm flowchart showed in Figure 1.

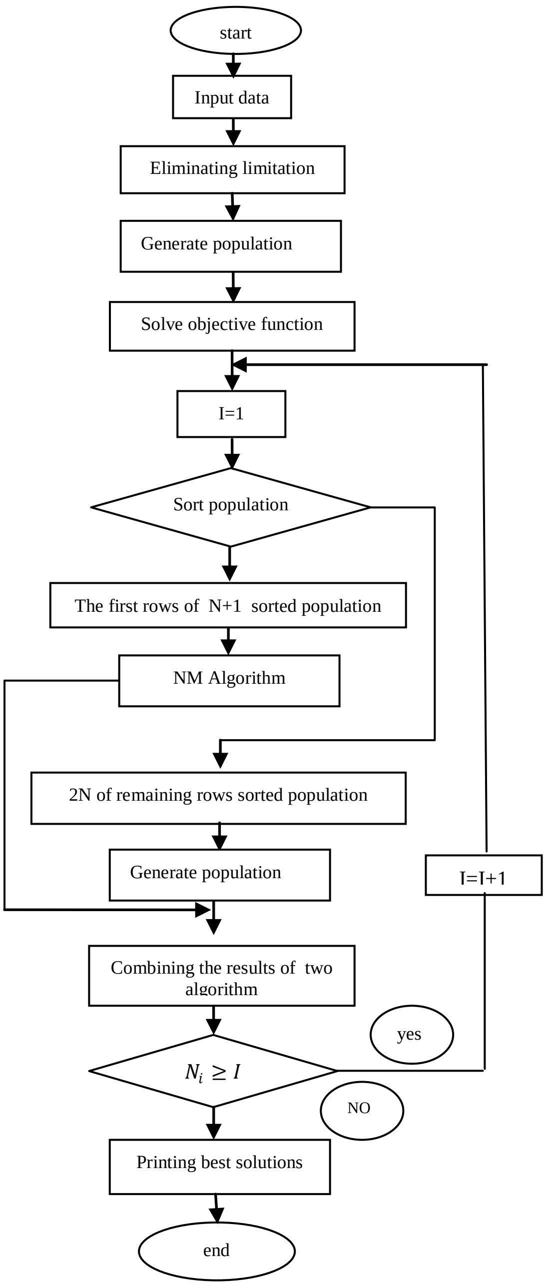

Figure 1: Folwchart of Hybrid algorithm

4. Results for using a hybrid algorithm in a real case study

The reconfiguration problem with an actual case study and the result from it are presented below. The case study is Gonabad city power distribution network with 26,475 kWh annual consumption and 26475 consumers. Figure (2) is the First arrangement and the current state of the network and Figure (3) shows the network topology after using a Genetic algorithm and Figure (4) is the result obtained from hybrid algorithm.

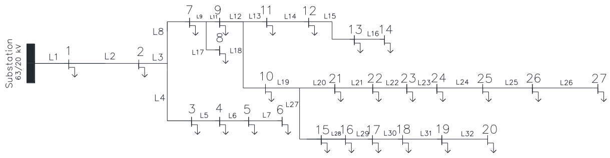

Figure 2: The Current state of the network PSO Algorithm

Table1: Network Specification

L3	2.326	L20	2.155
L4	6.499	L21	6.499
L5	2.245	L22	2.784
L6	2.115	L23	2.152
L7	3.012	L24	3.546
L8	5.750	L25	3.556
L9	1.562	L26	6.154
L10	1.486	L27	4.213
L11	3.879	L28	2.145
L12	2.014	L29	2.158
L13	2.152	L30	2.212
L14	2.879	L31	2.232
L15	5.626	L32	4.212
L16	3.656	L33	4.265
L17	4.507	L34	3.569

At the beginning the yearly average consumption for all consumers connected to the feeder measured. The GA algorithms have been executed with the parameters presented in table 2.

Table2: GA and Hybrid agorithm parameters

Hybrid Algorithm	
Population size	30
Iteration	100
ω_{min}	3
ω_{max}	0.4
C1	0.01
C2	0.0125

GA Algorithm	
Population size	30
Generation	100
Crossover	0.9
Mutation	0.125

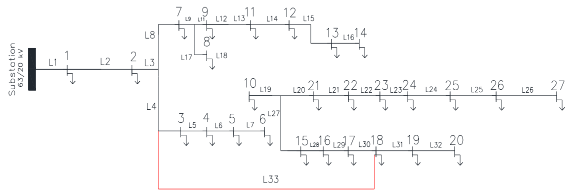

Figure3: Network configuration after using GA Alogorithm

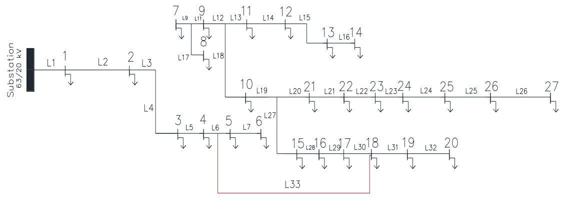

Figure4: Network configuration after using Hybrid Algorithm

Accordingly to Figure 3 and 4, displacement of branches in GA algorithm by connect and disconnect swithches cause to eliminating L18 and adding L33 and in Hybrid algorithm lead to eliminate L8 and adding L34.

As can be seen, by using the proposed algorithms voltage drop and power losses reduced considerably. In table 3 the simulation results by using these algorithms and the current state of the network are given.

Table 3: Simulation results

Result	Power losses	Voltage drop
The current state	18641.51	1.82
Genetic Algorithm	15145.34	1.56
Hybrid Algorithm	13983.32	1.43

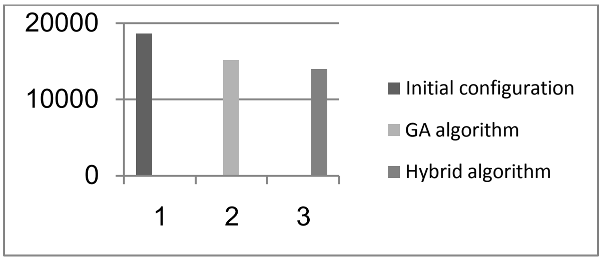

Figure 5: Power losses(W)

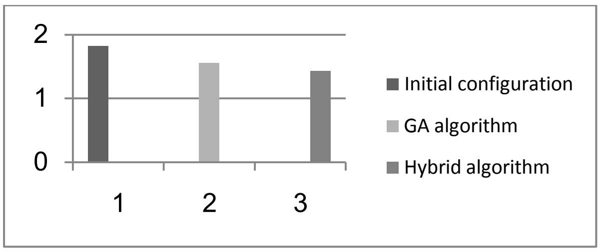

Figure 6: Percentage of voltage drop

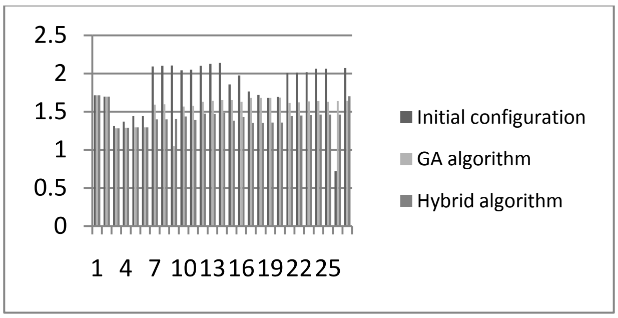

Figure 7: Voltage drop on each bass

As it can be seen from table 3, GA can reduce power losses and voltage drop 18% and 14% respectively. Another result from this table is that proposed Hybrid Algorithm reduces power losses for 24% and voltage drop for 21%.

5. CONCLUSION

In this paper, a new methodology for reconfiguration in distribution systems for power loss reduction using the displacement branches by using two methods is presented. The arrangement obtained from novel hybrid methodology achieves better results like better accuracy in power flow analysis and converge at minimum iteration. Also in the proposed algorithm network configuration remains radial and voltage and current constraints have been met. In general the Hybrid algorithm has a better solution in power losses and drop of voltage rather than GA. The Hybrid Algorithm computational time is more than GA but in the operation of this distribution network the goal is to reduce power losses with lesser switching action.

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