# Multi-Objective Reconfiguration of Radial Distribution System using AGA Technique

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## Abstract
Radial distribution system network is reconfigured by opening and closing the different section of tie-switches such that powers receivable from main substation to the various loads are re-routed. Radial distribution network reconfiguration is forming by closing one tie-switch and opening one sectionalizing switch to continue the basic radial topology. This paper deals with the optimal reconfiguration of Radial Distribution network Systems to achieve the best voltage profile and minimal real and reactive power losses. This is finding by perfect combination of feeders from each loop in the RDS to be switched out. A system (RDS) is an effective and to minimize the line losses, improve voltage profile, manage the load area and enhance system reliability. The multiple objectives of the network reconfiguration to minimize power loss, contravention of voltage constraints, as well as switching number. This Reconfiguration method is very efficient to reduce the losses and avoids difficult mesh check and hence reduces the computational burden. The effectiveness of the proposed method of AGA is used to demonstrate on 33-bus and 69-bus system of distribution system.

## Keywords
Radial Distribution System (RDS), Adaptive Genetic Algorithm (AGA)

## INTRODUCTION
Network reconfiguration change the network structure of distribution feeders by modify the open and close the status of the sectionalizing and ties switches. This system reduces the power loss, and also control the overloading of the network components. Hence, Network reconfiguration is a crucial task of distribution automation [9].

Recently Reconfiguration has a considerable interest. The reconfiguration methods can be two types as mathematical and heuristic method. The mathematical programming method is to solve optimal load deputed problems in distribution systems. It is presented a computationally clear Solution procedure to reduce power loss through reconfiguration. Optimal load flow analysis is applied to network reconfiguration, for loss minimization. While Formulating the loss reduction and load balancing as an integer programming problem, the load flow equations to calculate the power flow. And reduce the search space by proposing heuristic methods to finding solutions [1]

The process is a complicated and not differentiate, the combination of large number of switching in distribution system is a complicated, Heuristics and experts' experience-based approaches can only obtain sub optimal solutions. To find global optimal or, at least near global optimal solution, proposed a solution methodology using the Simulated Annealing (SA) algorithm for the reconfiguration, tuning the control parameters of the recombine schedule is extremely difficult and requires a consequential amount of computing effort [4]. The hybrid Genetic Algorithm approach to solve the reconfiguration, but they focus only on the minimum loss only.

In the area of AI-based techniques, the various GA-based methods have been developed for reconfiguration of RDS. It restricted the search space of GA by modifying the genetic operators. It presented a method based on GA for the loss minimization in distribution networks, using Metroid theory [5] and graph theory. It suggested a method based on GA to obtain the network configuration and formulated as a fuzzy multi-objective problem. The switching number is used in GA to ensure the radial structure. GA-based fuzzy multi-objective approach to solve the reconfiguration problem in RDS. Suggested a fuzzy multi-objective approach for feeder reconfiguration which incorporates a heuristic rule base [9]. In various AI techniques, investigated for multi-objective reconfiguration of RDS [6]. PSO and GA are population-based meta-heuristic optimization techniques and have potential to provide optimal solution. PSO is one of the modern meta-heuristic algorithms and has been found to be robust in solving continuous optimization problems. GA is inherently applicable in discrete variable optimization problems such as reconfiguration of RDS.

It presents a new method for multi-objective distribution network reconfiguration problem which combines GA and fuzzy adaptive technique. The objectives considered are minimization of real power losses, minimization of node voltages deviation, and minimization of switching number. The above objectives are transformed into fuzzy framework using a truncated sinusoidal and trapezoidal fuzzy membership functions [9]. The fuzzified objective function is solved using a new Adaptive Genetic Algorithm (AGA). The proposed AGA is developed with the help of graph theory in order to avoid mesh check at each stage of the genetic evolution. Moreover, the method involves the creation of initial population with better fitness using heuristic approach. This is reduces the overall computational time. The chromosome codification for GA is carried out using real numbers [2]. In the following section, the
formulation of the multi-objective reconfiguration problem in fuzzy framework is discussed.

FORMULATION OF RECONFIGURATION PROCESS

In this paper, the following objectives are considered for the reconfiguration of RDS:
1. Minimization of Real power loss
2. Minimization of Reactive Power loss
3. Minimization of node voltage constraint violation,
4. Minimization of switching number.

Minimization of Real Power Loss

Mathematically, the real power loss of the system may be expressed as

\[ P_{loss} = \sum_{i=1}^{n} R_i (\frac{V_i^2 + Q_i^2}{V_i}) \]

Where \( V_i \), \( P_i \) and \( Q_i \) are voltage, real power and reactive power at the sending end of the nth branch, respectively, \( R_i \) is the resistance of the nth branch, the equation used to minimize the real power loss. This is one of the main objectives of the reconfiguration of RDS. Let us define

\[ a_i = \frac{P_{loss i}}{P_{loss 0}} \]

Where \( P_{loss} \) is the real power loss of the ith radial system and \( P_{loss 0} \) is the real power loss of the base case radial system. The lower and upper bounds of \( a_i \), that is, \( a_{min} \) and \( a_{max} \) govern the desired degree \[ \mu_{Oi} \] of fuzzy satisfaction.

Minimization of Reactive Power Loss

The reactive power loss of the system is defined as

\[ Q_{loss} = \sum_{i=1}^{n} V_i I_i \sin \phi \]

Where \( V_i \) and \( I_i \) is voltage and current of the ith node, and reactive power loss is minimized for radial system.

Minimization of Node Voltage Constraint Violation

The membership function is to select a network which minimizes the node voltage constraint violations. Let us define

\[ V_i = \max \{|V - V_{ni}|\}; \quad \text{for } n = 1, 2, \ldots, N \]

Where \( V \) is the p.u. substation voltage, \( V_{ni} \) is the p.u. voltage at the nth node of the ith radial system and \( N \) is the total number of nodes of the system. The values of the coefficients \( K_3 \) and \( K_4 \) are problem dependent and are obtained using curve fitting.

Minimization of Switching Number

The reconfiguration, the number of switching operations should be as minimal as possible in order to reduce the operating cost, switching transients and to enhance the life of the switchgears.

Membership Function (Trapezoidal Function)

\[ \mu_{S_i} = \begin{cases} 1; & N_s \leq d_{min} \\ \mu_{S_i} = k_1 x N_s x k_2; & d_{min} < N_s < d_{max} \end{cases} \]

Unlike sinusoidal fuzzy membership function, a trapezoidal fuzzy membership function is considered for switching number because the cost of switching operations is linearly related with the switching number \( N_s \).

DEGREE OF OVERALL FITNESS FUNCTION

The proposed algorithm, a new operator called ‘max-geometric mean’ has been introduced to determine the degree of overall fuzzy satisfaction. For the ith radial system, the degree of overall fuzzy satisfaction is defined as

\[ \mu_{Oi} = (P_{loss i} x Q_{loss i} x V_i x \mu_{S_i})^{1/4} \]

The network with maximum degree of overall fuzzy satisfaction, \( \mu_{Oi} \) will give the best compromising solution. Therefore \( \mu_{Oi} \) is considered as the fitness function for the GA [8].

ADAPTIVE GENETIC ALGORITHM

The conventional GA needs modification using some engineering knowledge base to make it compatible with the problem of reconfiguration of RDS. In the proposed AGA, these infeasible individuals are transformed into the feasible individuals using graph theory. The fundamental loops are determined for the meshed network by closing all tie-switches. The number of fundamental loops of the meshed network is equal to the number of tie-switches of the system and is given by the relation:

\[ L = E - N + 1 \]

Where \( E \) is the total number of elements and \( N \) is the total number of nodes of the network. Thus, the length of chromosomes for GA is given by \( L \). Each gene of a chromosome, denoted by a real number, will be the switch to be open to maintain a feasible radial configuration. The modified genetic operators ‘accentuated crossover’ and ‘directed mutation’. Are further modified to generate feasible individuals during initialization, crossover and mutation. The generate the possible individuals and confirm to used loop vectors, In the proposed AGA, in addition to ‘loop vectors’, the ‘common branch vectors’ and ‘prohibited group vectors’ are introduced to avoid the generation of infeasible individuals during each stage of the genetic evolution.

PROPOSED AGA

Let us consider a 33-bus system shown in Figure 1. For this system \( E = 37 \), \( N=33 \) and \( L =37-33+1 = 5 \). Therefore the network topology suggests five loop vectors, and seven common branch vectors as given in Tables 1 and 2, respectively. The prohibited group vectors and the corresponding islanded principal node(s) for the system may be obtained from Figure 1, as shown in Table 2. For the distribution system shown in Figure 1, total five switches have to be opened to form an individual to maintain the radial topology, one from each loop vector as per Rule. Let the individual \([6 \ 21 \ 14 \ 22 \ 5]\) is created at any stage of evolution, which is not a feasible individual according to Rule, since both 5, 6 \( \notin \ C_{13} \). If this individual is selected, then node 6 will be islanded.

Considering another individual \([7 \ 8 \ 34 \ 3 \ 25]\), which is also not a feasible individual according to Rule, since 7
$\epsilon C_{34}, 3 \epsilon C_{12},$ and the prohibited group vector $R_5 = \{C_{12}, C_{23}, C_{34}\}$. If this individual is selected, then the principal node 5 will be islanded. There are many more such infeasible individuals that exist until or unless they are guided by Rule 2 and Rule 3, in addition to Rule.

For crossover, say parent $P_1$ is $\{7, 33, 12, 25, 31\}$ and parent $P_2$ is $\{33, 9, 13, 25, 34\}$. For two-point crossover, let first and third positions are randomly selected crossover sites. Similarly, during mutation, let the individual to be muted is $\{4, 10, 13, 23, 7\}$. For instance, let fourth position of the individual is selected randomly as the mutation site. Therefore the switch 23 of the individual must be replaced with any other switch, say switch 26.

**SIMULATION RESULTS**

A 33-bus and 69-bus RDS was considered for the Power Loss minimization with the constraint of Voltage. Adaptive Genetic Algorithm techniques have been conducted on the 33-bus and 69-bus system.

**Results from 33-bus**

The performance of 33-bus RDS is summarized in Table 4, where the best chromosome after 50 generations is taken. It is discovered that the total real power loss in the lines of RDS reduces from 211.22 kW to 128.15 kW as shown in Figure 2.

The reactive power loss reduced from 143.18 kVAr to 102.28 kVAr for 33 bus system as shown in Figure 3.

The bus voltage reduced from 0.9093 to 0.862001. The time consumed was 0.453 sec. for 33 bus system shown in Figure 4, the best voltage profile may be achieved through appropriate tuning.
Results from 69-bus
The performance of 69-bus RDS is summarized in Table 5. Where the best chromosome after 50 generations is taken and it is discovered that the total kW loss in the lines of RDS reduces from 228.87 to 136.23 kW as shown in Figure 6.

The reactive power loss is reduced from 143.18 to 59.38 kVAR for 69 bus system as shown in Figure 7.

It is also recorded that the bus voltage improves from 0.9428 to 0.9495. The time consumed was 4.203 sec for 69 bus system as shown in Figure 8. The best voltage profile may be achieved through appropriate tuning. Appropriate tuning may be done through proper selection of NC.

Table 5: Details of Optimal solution-69 Bus system.

<table>
<thead>
<tr>
<th>State</th>
<th>Base case</th>
<th>Optimal case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lines switched out</td>
<td>69-70-71-72-73-74</td>
<td>71-25-66-64-59</td>
</tr>
<tr>
<td>Real Power Loss in kW</td>
<td>228.87</td>
<td>136.23</td>
</tr>
<tr>
<td>Reactive power loss in kVAR</td>
<td>143.18</td>
<td>59.38</td>
</tr>
<tr>
<td>Bus voltage in p.u</td>
<td>0.9428</td>
<td>0.9495</td>
</tr>
</tbody>
</table>

CONCLUSION
The paper presents a new method for multi-objective reconfiguration of RDSs in AGA. The objective functions of different objectives have been formulated into a single objective function by determining geometric mean of their fuzzy membership functions. This provides the best compromising solution without the violation of any operating constraints. The single objective function is then optimized with the help of GA which is adapted using graph theory to avoid tedious mesh check and thus creates feasible individuals at each stage of the genetic evolutions. Moreover, the proposed method employs heuristics to create feasible initial population with better fitness. This strategy reduces the computational burden of GA which results in less computational time. The proposed method of AGA has been applied on medium and large-sized distribution systems and the results are compared with other existing. The application results show that the proposed method provides a promising tool for multi-objective distribution network reconfiguration problem. The proposed method can be extended to deal with more objectives without any significant computational burden to solve reconfiguration problem of RDS.

REFERENCES


Biography of Author(s)

Srinivasan C received the M.E (Power System Engineering) from K.S.Rangasamy College of Technology, Tiruchengode, India. He is presently working as Assistant Professor in the Department of Electrical and Electronics Engineering of K.S.Rangasamy College of Technology, Tiruchengode, India.