# Reconfiguration of Distribution Networks with Presence of DGs to Improving the Reliability

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***Abstract***
*In this paper, the network reconfiguration in the presence of distributed generation units with the aim of improving the reliability of the network is studied. For this purpose four reliability parameters in the objective function are considered, which is average energy not supplied system average interruption frequency index, system average interruption duration index and momentary average interruption frequency index. The new method will be normalized objective function. Another suggestion of this paper are considering the different fault rates, locating time of faults type and prioritization of customers based on their importance. This nonlinear problem has optimized by particle swarm optimization (PSO) algorithm.*

*Keywords: Reconfiguration, DG, reliability, fault rate, locating time*

## 1. Introduction

Distribution Networks are last part of the power system and fed various consumers directly. This pat of system has different challenges. One of these challenges is reliability. In this network, diversity of equipment and direct communication with consumers has caused the level of reliability is low. Various solutions have been proposed to improve the reliability of distribution Network. But the reconfiguration of network is one of the best methods of improving reliability, because has very low cost.

Reconfigurations can be defined as "the process of changing the configuration of the power system by changing the switches situation to satisfy the operation constraints." When faced with reconfiguration, system operators need to change the status of the switches to minimize faults effects of network loads. In fact, in reconfiguration path from the source to the load change so that the network is radial and system reliability is improved. Operation constraints can be as follows:
- Radiality of the network to be maintained
- The new network will fed all busses.
- Loads are not more than network capacity and production
- Busses voltage and network equipment are within the allowable range.
- Current lines and equipment are within the allowable range.

By considering the importance of network reconfiguration, many studied has been published in this field. Published studied have been classification in five categories: evolutionary techniques, particle intelligence, innovative, combinational and analytical-probability.

One of the general methods of artificial intelligence is evolutionary techniques. This technique is proposed by Darwin using the fundamental concept of evolution proposed. This technique are randomly generated an initial population and then using the several stage (e.g., mutation, interaction, etc.) extract the optimum response among them. Genetic algorithms, differential evolution algorithm, taboo search and evolutionary algorithms including methods based on evolutionary techniques that in published paper have been proposed to solve reconfiguration problem on distribution network [1-10].

Particle intelligence is one of other intelligence methods that after evolutionary techniques, is the general optimization methods. These techniques are base on trying creatures like fishes, ants and bees to live in a group with the aim of finding food or immigration [11-18].The innovative techniques with unique and new methods that have drawn often basic concepts solve the complex-nonlinear problems [19-24]. Each technique has some advantages

and disadvantages. Researchers benefit from capabilities of different algorithms by combining two or more intelligent technique [25-28].

In [29] is proposed a new method for improving reliability by reconfiguration using Interval analysis techniques with regard to uncertainly to maximize reliability improvement and power losses reduction. Case studies show the efficiency of proposed method for reconfiguration. In [30], a new probability based method is presented for the reconfiguration to reduce the total cost of switch and losses costs. With regard to time-varying loads, the proposed method is able to achieve an optimum balance between the number of switching and losses. Several experiments show the superiority of the proposed method and the results are compared with certain methods in several states.

However, these methods have disadvantages and advantages with respect to each other, but experience has shown that methods based on particle intelligence technique is appropriate compared to other techniques. One of the most widely used optimization method based on particle intelligence is PSO algorithm that has advantages over other algorithms [31].

In this paper, the reconfiguration of the distribution network is done with DGs for improvement of distribution network reliability using the PSO algorithm. Of course, by considering this subject that the distribution networks have various consumers that their supplying have not same importance and they should be prioritize from reliability viewpoint. Therefore, an important issue in the network reconfiguration is prioritization consumers and applying the importance of the consumers in the reconfiguration. Also, the fault rate changes during network section-by-section should be considered that in this paper is studied.

## 2. Objective Function

The main challenge in this step is the introduction of objective function. By considering that defined reliability indexes and power losses in the objective function have different amounts, normalization techniques used to incorporate these parameters in the objective function. Thus the values of the objective function terms are divided to before placement values. With this technique, each parameter is normalized based on logical and scientific amounts.

$$OF = \sum_{k=1}^{ny} \left\{ \frac{SAIDI_k}{SAIDI_0} + \frac{SAIFI_k}{SAIFI_0} + \frac{AENS_k}{AENS_0} + \frac{MAIFI_k}{MAIFI_0} + \frac{Loss_k}{Loss_0} \right\} \tag{1}$$

Where, k and 0 indices are the values before and after the reconfiguration, respectively. In some papers, such problems are solved by weighting coefficients and these coefficients are set by the user (the sum of the coefficients equal to 1). These methods are not suitable methods for solving these problems and actually effect of parameters with low values decreases on objective function. While in the normalization techniques, the impact of each parameter is same on objective function.

## 3. The Constraints of Optimization

Problem constraints are consists of two parts. The first part of the DG constraints are consists of the number, active and reactive power any source. Other provisions constraints are the allowable bus voltage so that during the islands, the voltage on the load should not exceed limits.

### 3.1. The Convergence Condition of Power Flow

Corrective power flow is the first step in the placement and determines the capacity of the DGs. While the power system load flow problems seems is simple, but it is important on problem results. Equation (2) and (3) show the active and reactive power flow relationships.

$$P_{gi} - P_{di} - V_i \sum_{j=1}^{n} V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) = 0 \tag{2}$$

$$Q_{gi} - Q_{di} - V_i \sum_{j=1}^{n} V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) = 0 \tag{3}$$

### 3.2. The Balance of Power

Produced power on Slack bus and distributed generation units should be equal with sum of power losses and total loads according equation (4).

$$P_{Slack} + \sum_{i=1}^{N} P_{DGi} = \sum_{i=1}^{N} P_{Di} + P_L \tag{4}$$

### 3.3. Range of Produced Active and Reactive Power Distributed Generation Units

The produced active and reactive power distributed generation units don't must be more than capacity of these units.

$$Q_{DGi}^{min} \leq Q_{DGi} \leq Q_{DGi}^{max}$$
$$P_{DGi}^{min} \leq P_{DGi} \leq P_{DGi}^{max} \tag{5}$$

### 3.4. Range of Network Losses

If you add DG in non-optimal point increase power transmission losses thus call will not be accepted.

$$\sum Loss_k (withDG) \leq \sum Loss_k (withoutDG) \tag{6}$$

### 3.5. Range of Bus Voltage

Installation of distributed generation units should not increase a bus voltage greater than (1.05 pu) or reduce less than (0.95 pu).

$$|V_i|^{min} \leq |V_i| \leq |V_i|^{max} \tag{7}$$

### 3.6. Range of Current Flow through Line

The proposal to install distributed generation units should not increase the current flow through lines more than nominal value, in fact, these limits shows current limits.

$$|I_i| \leq |I_i|^{max} \tag{8}$$

In the above equations
$V_i$: voltage of $i^{th}$ bus
$P_{ij}$ active power flow from bus i to j
$P_{gi}$, $Q_{gi}$: Production of active and reactive power at bus i
$P_{di}$, $Q_{di}$: active and reactive loads at bus i
$V'_s$, $\delta'_s$: amount and angles of bus voltage
$Y_{ij}$: admittance matrix

## 4. The Optimization Algorithm

The optimization algorithm used in this paper is PSO algorithm that can be expressed with bellow steps [32]:

### 4.1. Random Amount of a Particle in Society with D Dimensional Search Space

*For each particle*
*   Initialize particle*
*End*

Algorithm PSO is population-based algorithm, which means that many particles try to find optimal point. The first step is population of random population that is called primary population, respectively. Usually the numbers of primary particles are between 10 up to 40, but for most of the problems, 10 particles are sufficient. To solve specific and complex problems, it can be 100 or 200 particles. The algorithm should be written so that particles are within the range of the search space. To initialize a particle between two ranges, the following equation should apply:

$$Rand\left(0,1\right)\times\left(b_u - b_i\right)+b_i \tag{9}$$

Where, Rand (0, 1) shows the random number between 0 and 1. $b_u$ is the upper bound of the range and $b_i$ is the lower bound of the range. Note the size of the population don't change during the optimization process.

## 4.2. Assessment of the Particles Fitness

*Do*
  *For each particle*
   *Calculate fitness value*
   *If the fitness value is better than the best fitness value in history*
   *Set current value as the new personal best*
  *End*

The purpose of the fitness is creating a significant, measurable and comparable amount for quality assessment. Optimization results show that the used particle is how much good or bad. After creating population, amount of assessment must be calculated for each particle. Each particle has a proportion that it is called the "best part". This particle is the best point of the same particle untie now. After the calculation of fitness, it's compared with best particle fitness. If current fitness is better, it will create the new particle.

## 4.3. Record the Best Point of Each Particle, $p_{best,i}$, and Overall Best Point, $g_{best}$

Choose particle with best fitness value of all particle as the global best Particle swarm optimization, the overall optimum looking stems. In fact, the best fit of all has been the best overall value. Thus all particles are able to move smoothly to the best neighbor.

## 4.4. Update the Velocity Vector and the Vector Position of Each Particle

*For each particle*
  *Calculate particle velocity*
  *Update particle position*
*End*

This step is necessary for every particle and it is consisted of two parts, speed and position. Each particle update the speed and it's position based on gives the following equations:

$$v_{id}^{k+1} = wv_{id}^{k} + c_1 r_1\left(pbest_i^{k} - x_{id}^{k}\right) - c_2 r_2\left(gbest_i^{k} - x_{id}^{k}\right) \tag{10}$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1}$$

Where:
W: weight of inertia
$C_1, C_2$: acceleration factors
$r_1, r_2$: two random number in the range [0,1]
$p_{best,i,k}$: The position of $i^{th}$ particle at $k^{th}$ iteration
$g_{best,k}$: The overall situation at $k^{th}$ iteration

## 4.5. Repeat 2 up to 4 Steps to Satisfy Stopping Criterion

Algorithm until a stopping certain condition is satisfied continues. This condition can be one of the following:
• Achieve the highest number of repeat
• Achieve the highest number of repeat after the latest updates $g_{best}$
• Determine a predefined amount of fitness
• Update velocity near zero
Maximum number of iterations to run the algorithm is usually simplest stopping criterion.

*For   each particle*
  *Initialize particle*
*End*
*Do*
  *For each particle*
   *Calculate fitness value*
   *If the fitness value is better than the best fitness value in history*

         *Set current value as the new personal best*
       *End*
    *Choose particle with best fitness value of all particle as the global best*
    *End*
    *For each particle*
       *Calculate particle velocity*
       *Update particle position*
    *End*
   *While maximum iteration*

## 5. Case Studies

For case studies, 69 busses network is used. The simulation was performed using MATLAB software. Values of PSO algorithm, W, $C_1$ and $C_2$, are respectively, 4, 1 and 4. Four scenarios are designed for properly analyze the results:

- Scenario 1: different fault rates and customers prioritization
- Scenario 2: the same relative fault rate
- Scenario 3: regardless of customer prioritization
- Scenario 4: relative fault rate is the same regardless of the customer prioritization

### 5.1. Reconfiguration without the Distributed Generation Units

Four scenarios applied on proposed 69 busses network without DG. The results in Table 1 are listed.

Table 1. Results of the reconfiguration without DG

| Scenario | OF | $P_{loss}$ | AENS | MAIFI | SAIDI | SAIFI |
|----------|------|--------|-------|-------|--------|-------|
| 1 | 4.38 | 119.99 | 48.96 | 9.76 | 103.99 | 40.23 |
| 2 | 4.40 | 120.55 | 49.53 | 9.82 | 104.26 | 40.15 |
| 3 | 4.38 | 120.52 | 49.42 | 9.68 | 104.19 | 40.19 |
| 4 | 4.41 | 120.95 | 49.35 | 9.84 | 104.82 | 40.55 |

According to the results shown in table (1) In general, the first and fourth scenarios may provide the best and worst response, respectively. After the first scenario, the third scenario is a better response. It also can be argued that, second, third, first and fourth scenarios have best results from point SAIFI index, respectively. In SAIDI, respectively first, third, second and fourth scenarios show a better response. The scenarios 3, 1, 2 and 4 are best from MAIFI index viewpoint. AENS and losses can have a similar situation with SAIDI. Finally, the objective function is prioritized such as one, three, two and four scenarios, respectively. Table 2 is provided the switch codes in the absence of distributed generators.

Table 2. Switch codes of reconfiguration without DG

| Scenario | Switch codes |
|----------|--------------|
| 1 | 69 61 13 12 57 |
| 2 | 13 10 18 61 56 |
| 3 | 14  9 61 56 70 |
| 4 | 62 19 10 57 13 |

### 5.2. Reconfiguration with DG

In this case, DG enters the reconfiguration process. A DG is applied on network and its effect on the reliability parameters and the objective function simultaneously with reconfiguration are studied. Table 3 lists the results of the study.

Table 3. results of reconfiguration in the presence of a DG

| Scenario | OF | $P_{loss}$ | AENS | MAIFI | SAIDI | SAIFI |
|---|---|---|---|---|---|---|
| 1 | 3.90 | 108.31 | 45.14 | 8.28 | 93.05 | 36.14 |
| 2 | 4.06 | 114.44 | 46.11 | 8.75 | 94.37 | 38.21 |
| 3 | 3.99 | 112.60 | 46.10 | 8.52 | 93.26 | 37.18 |
| 4 | 4.09 | 113.17 | 47.12 | 8.91 | 92.17 | 39.18 |

According to Table 3, it can be claimed that the losses can be significantly reduced compared to before. However, still, first and fourth scenarios may provide the best and worst response, respectively but differences fourth scenarios and later scenario (the second scenario) declined. It is clear that scenarios 1, 3, 2 and 4, respectively, have the best answer for SAIFI index. For SAIDI strange thing occurred and scenario 4 has the best and scenario 2 has the worst answer. MAIFI is similar to the SAIFI. About AENS, priority is similar to SAIFI but difference second and third scenarios are lower. Scenarios first, third, fourth and second, respectively, displays the lowest power losses. The results of the five parameters of the objective function are shown that the succession scenarios for the objective function are 1, 3, 2 and 4. Location and capacity of DG units as well as switch codes from the applied a DG is shown in Table (4).

Table 4. switch codes and DG of reconfiguration in the presence of DG

| Scenario | switch codes | place (capacity) of DGs |
|---|---|---|
| 1 | 69 13 12 61 52 | (400)20 |
| 2 | 57 62 69 12 19 | (500)13 |
| 3 | 55 13 18 61 10 | (450)11 |
| 4 | 69 62 19 14 57 | (600)21 |

## 6. Conclusion

In this paper, reconfiguration of distributed networks with presence of DGs to improve the reliability and power loss has been studied. For this purpose, four indices of reliability indices has been considered in objective function consists of: System average interruption frequency index (SAIFI), System average interruption duration index (SAIDI), Momentary average interruption frequency index (MAIFI), average energy not supplied (AENS). It has been optimized with PSO algorithm. Simulation has been done on 69 busses network with four scenarios. The simulations results have shown that relative fault rate and the priority of customers are effective on reliability and relative costs.

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