# Optimal Switch Placement in Radial Distribution System Using GA and PSO

Ashish Ranjan, J N Rai

**Abstract**— Distribution Reliability worth assessment is currently receiving considerable attention as it provides the opportunity to incorporate the cost or losses incurred by utility customers as a result of Power failure in the overall analysis of system costs & benefits. Distribution system reliability has acquired importance in these days, because the distribution system performance can directly affect the customers. Reliability evaluation of distribution system assesses the adequacy of the load point in regard to provide a suitable supply to the customers. The distribution system reliability mainly deals with the interruption frequency and interruption duration of customers. If these values are large, the reliability of system is poor. In this paper, the reliability of the distribution network is evaluated for 13 Bus system in`a radial distribution system, considering no alternate supply. Genetic algorithms (GA) and particle swarm optimization (PSO) are the most famous optimization techniques among various modern heuristic optimization techniques. These two approaches identify the solution to a given objective function, but they employ different strategies and computational effort. This paper presents the application of the PSO and GA optimization techniques for optimal switch placement in distribution system. The design objective is to enhance distribution system reliability.

**Index Terms :**Distribution system,Radial Feeders , Reliability Particle swarm optimization, Genetic algorithm, Reliability, switch placement.



## 1 INTRODUCTION

The percentage of system faults in a distribution network is more compared than that in other parts of a power grid system [1]. The reduction of momentary and sustained outages reacting more quickly to system disturbances can be achieved by protection schemes and leading-edge equipment, such as modern remote-controlled switches, breakers, reclosers, and fault indicators. In order to achieve a high level of reliability, more investment should be accomplished by the utilities and the best locations for installing these switches should be found so that the most possible benefit is gained. Determination of the best switch location is an optimization problem.

The selection of an adequate number of switches and their locations is a difficult task in distribution system planning . Utilities use their past experience , customer data and other considerations in selecting a suitable number of switches. . Reference [8] provides four rules to locate protective devices in order to improve reliability. The reliability index used in [8] is the average number of minutes per customer year (SAIDI) [2]. Genetic algorithms are used in [9] to determine switching device locations.

To improve system reliability for distribution systems under fault conditions,switch placement schemes are proposed by various algorithms such as genetic algorithm(GA)[3],particleswarm optimization (PSO) [4]. Kennedy and Eberhart [4] introduced the idea of continuous particle swarm optimizer in 1995 and many researchers have been developing and modifying different versions of the PSO in different disciplines.

The discrete binary version of PSO for discrete optimization problems has been introduced in 2001. In addition, researchers frequently model continuous domain problems in binary terms, and they solve those problems in discrete high dimensional spaces, featuring qualitative distinctions. In recent years, PSO with fast convergence has opened up a big opportunity to be employed in power systems [5].

In [6] PSO algorithm is used for Determine the optimum number and location of switches in distribution system and results on 13 bus test system shows this meth-

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od is comparable to genetic algorithm with this problem.

## 2 Problem Formulation

The flow of power is always from the substation transformer downstream to the individual customers for the typical radial feeder. For a fault anywhere on the feeder, only one recloser operates, which is the closet to the fault typically, to minimize the number of affected customers. As an example, a radial feeder with a substation breaker, three reclosers is shown in Fig. 1. Assuming there are no distributed the first recloser upstream the fault will operate in the presence of a fault anywhere on the line. Then the customers located downstream the recloser will lose service. However, if fault occurs between bus2 and bus 3 then substation breaker will trip first after that recloser 2 will operate allowing the portion of the feeder downstream from it to operate as an island so that we can continue supply up to bus 2.

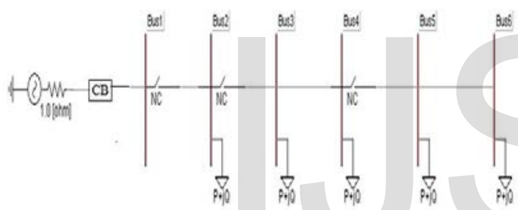


Fig.1. Radial feeder with three reclosers.

Failure mode analysis (FMA) is an effective way to evaluate a simple network reliability level. But if network involves a large number of components, the failure events that lead to load point outage will become too much to be calculated by directly using FMA.

In distribution system probability of failure is function of length. Longer is the length higher is the failure probability of segment.

Let,

$q_1$ = probability that segment 1 may fail

$q_2$ = probability that segment 2 may fail

$q_3$ = probability that segment 3 may fail

The failure probability that load 3 may fail will be given

As $R_3 = p_1.p_2.p_3$ ; probability that load will serve So failure of load = $Q_3 = 1- R_3$

For Load 2

$Q_2=1-R_3$ ; because load 2 will serve if all segment will serve similarly for load 1.

For the calculation of reliability we assume that one fault occurs at a time i.e. single outage.

When any fault occurs then first CB will operate ,all load disconnected . Now rerclosure of faulted segment will operate to isolate the fault then close CB and resume the supply to healthy segment. Once repair are over then close the reclosure and resume the supply to all system.

Here , customers at the end of radial feeder have lower reliability . Now , on the besis of above method , we find a matrix beween load point and segment. This matrix is helpful to calculate the reliability indices of the system. When fault occur in load point 1 then C.B. will trip first and all the load point will interrupted till load point 1 is not repaired. Hence the failure rate of all load point is same as $\lambda 1$ and repair rate is r1. When fault occur in branch 2 then C.B. will trip at the source end and the failure rate of all load point will be same as $\lambda 2$.This matrix is helpful to calculate the reliability indices of the system. When fault occur in load point 1 then C.B. will trip first and all the load point will interrupted till load point 1 is not repaired. Hence the failure rate of all load point is same as $\lambda 2$.Now isolator 2 will operate so we can resume supply up to branch 1 within riso time but the repair rate of branch 2 and 3 will be same $r_2$, similarly for branch 3 and 4 and so on. Here $\lambda$ is failure rate and r is repair rate.

riso= Additional time required to locate the fault and open the recloser of faulted segment and reclose the circuit breaker to resume the supply is known as riso.

Table 1

The equivalent failure rate and repair rate of the system

| Load Point 1 ,L1 | | | |
|---|---|---|---|
| Seg/Load | | r | U |
| 1 | 1 | r1 | 1*r1 |
| 2 | 2 | riso | 2*riso |
| 3 | 3 | riso | 3*riso |
| | equ1 | r equ1 | s1 |
| Load Point 2 ,L2 | | | |
| 1 | 1 | r1 | 1*r1 |
| 2 | 2 | r2 | 2*r2 |
| 3 | 3 | r3 | 3*r3 |
| | equ2 | r equ2 | s2 |
| Load Point 3 ,L3 | | | |
| 1 | 1 | r1 | 1*r1 |
| 2 | 2 | r2 | 2*r2 |
| 3 | 3 | r3 | 3*r3 |
| | equ3 | requ3 | s3 |

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The basic system shown in Figure 1 has switching devices. This system has reasonabl bly high reliability as interruption durations and energy losses are minimized due to the installed sectionalizing switches .

Reliability indices such as the system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI), system unsupplied energy due to power outages (ENS) can be calculated [10,[ 11] for this system. The reliability indices, SAIDI, ENS can be calculated [10],[11], using Equations 1 and 2.

$$SAIDI = \sum_{j=1}^{nj} \sum_{k=1}^{nk} (\lambda_j r_j P_{k)} / (\sum_{l=1}^{nl} Pi) \quad \text{(Hrs per customer per year)} \quad (1)$$

$$ENS = \sum_{i=1}^{ni} \sum_{j=1}^{nj} \sum_{k=1}^{nk} L_k r_j \lambda_j \quad \text{(Mwh/year)} \quad (2)$$

Where,

nk= number of load points that are isolated due to a contingency j.

nj = number of outage events,

ni = no. of load steps

Lik = load at load point k for the ith step of load duration curve at load point k

rj = average outage time of contingency j

nl = total number of load points

Pk= number of customers connected to a load point k.

The objective function for this problem is as follows:

Max profit=(ENSwsw-ENSws)*tariff -Ns*switchcost (3)

Subject to,

Switch position>=1;

Switch po sition<= n—1;

Where,

ENSwsw = ENS without any switch in radial distrbution system.

ENSsw =ENS considering switches in the system .

Ns=Number of switches placed in the system

n is total number of bus.

A. Genetic Algorithm.

In this paper GA is used to find the optimum allocation of switches in the radial distribution feeder. GA is an iterative procedure which begins with a randomly generated set of solutions referred as initial population. For each solution in the set the objective function and fitness are calculated. On the basis of these fitness functions, pool of selected population is formed by selection operators, the solution in this pool has better average fitness than that of initial population. The crossover and mutation operator are used to generate new solutionwith the help of solution in the pool. Here in thispaper, matlab genetic algorithm tool box is used for optimum allocation of switches. used to generate new solution with the help of solution in the pool. Here in thispaper, matlab genetic algorithm tool box is used for optimum allocation of switches.

A simple Genetic algorithm is as follows:

Step 1: Randomly generate initial population strings.
Step 2: Calculate the fitness value for each string in the population
Step 3: Create the pool after selection.
Step 4: Create offsprings through crossover and mutation operation.
Step 5: Evaluate the offsprings and calculate value for each solution.
Step 6: If the search goal is achieved, or an allowable generation is attained, return the best chromsome as solution; otherwise go to step 3.

*B. Particle Swarm Optimization (PSO)*

PSO is an optimization method inspired by the collective behaviour patterns of birds flocks and fish schools or of human communities that evolve by information exchange among particles in a group.[12]. In this paper mixed-integer PSO (MIPSO) method, composing both the original version and discrete version of PSO, can simultaneously deal with the continuous/discrete control variables in the problem space . Therefore ,The MIPSO method can be used to solve mixed integer opt- The MIPSO method can be used to solve mixed-integer optimization problems. In discrete binary PSO [13], the relevant variables are interpreted in terms of changes of probabilities. A particle flies in a search space restricted to zero and one in each direction and each vid represents the probability of member xid taking value 1. The update rule governing the particle flight speed can be modified accordingly by introducing a logistic sigmoid transformation function:

$$S(vid) = 1/(1 - \exp(-vid)) \quad (4);$$

The velocity can be updated according to this rule

If rand()<S(vid) ,then $x_{id} = 1$; or else xid = 0. The maximum allowable velocity Vmax is desired to limit the probability that member xid will take a one or Zero value. The smaller the . The smaller the Vmax is, the higher the chance of mutation is for the new individual. .

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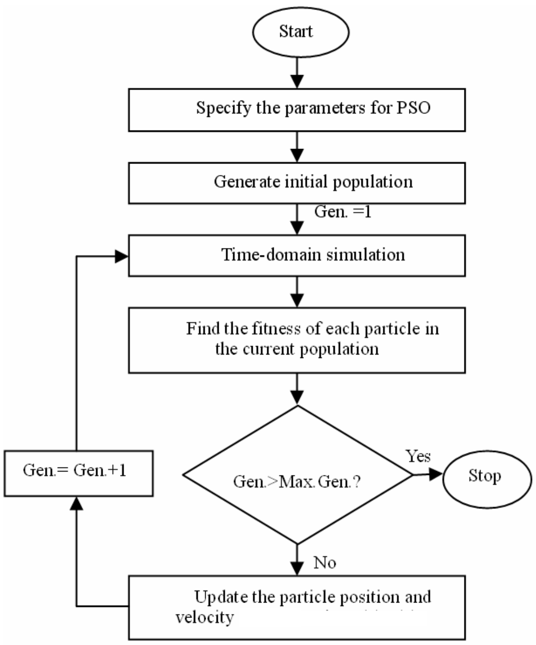


Fig 2. Flow chart of PSO

## 3 NUMERICAL EXAMPLE AND RESULT

In this section, 13 bus systems are used to test the proposed method. The data used in the program are listed in table. Tariff and riso are 7.0 and 0.5 respectively and maximum number of iteration is 200.

Table 2
LINE DATA FOR 13 BUS SYSTEM

| Line no | Failure rate (failure per year) | Repair rate (hrs) |
|---|---|---|
| 1 | 0.10 | 2.0 |
| 2 | 0.15 | 2.5 |
| 3 | 0.20 | 3.0 |
| 4 | 0.20 | 3.0 |
| 5 | 0.15 | 2.25 |
| 6 | 0.10 | 2.0 |
| 7 | 0.10 | 2.0 |
| 8 | 0.15 | 2.35 |
| 9 | 0.20 | 3.25 |
| 10 | 0.20 | 3.0 |
| 11 | 0.15 | 2.25 |
| 12 | 0.10 | 2.0 |

Table 3
LOAD DATA FOR 13 BUS SYSTEM

| Load points | No. of customer | Demand(Kw) |
|---|---|---|
| 2 | 100 | 1000 |
| 3 | 200 | 2000 |
| 4 | 300 | 3000 |
| 5 | 200 | 4000 |
| 6 | 300 | 5000 |
| 7 | 100 | 2000 |
| 8 | 400 | 3000 |
| 9 | 100 | 1000 |
| 10 | 200 | 4000 |
| 11 | 300 | 1000 |
| 12 | 100 | 2000 |
| 13 | 400 | 1000 |

### 3.1 Conclusion for 13 bus system

From figure 3 , after Seven Switches , the variation in SAIDI is negligible. From fig.4 ,after 7 switches , profit is comparatively less. From fig 5 both GA & PSO are providing almost same result for 13 bus system but GA is more dominant. So for 13-bus system seven switches can be placed to get maximum reliable supply and more profit. From above table 4 we can conclude that after 7 switches GA and PSO differ a lot in profit. From graph it is clear that SAIDI decreases as switch increases but after 7 switches variation in SAIDI is very less. The profit also decreases after 7 switches and no more rapid variation in profit. Reliability of system is also good. In table 4 the comparison of profit by GA and PSO methods are given.

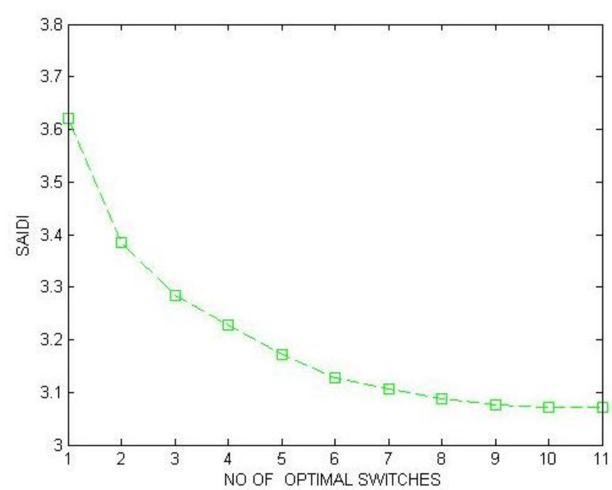

Fig.3. SAIDI vs Optimal Switch

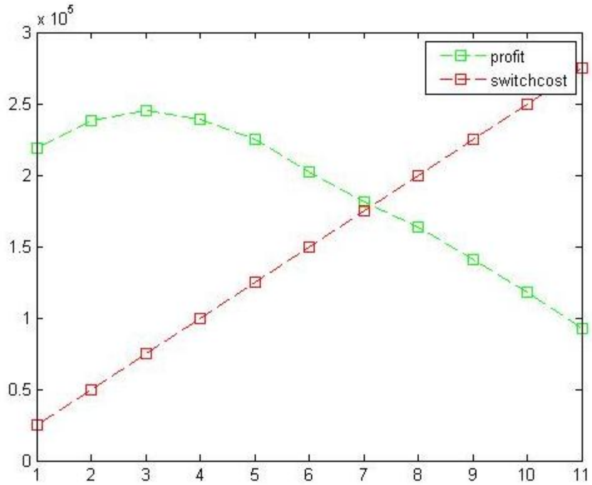


Fig.4.Variation of Profit ,Switch Cost Vs Switch

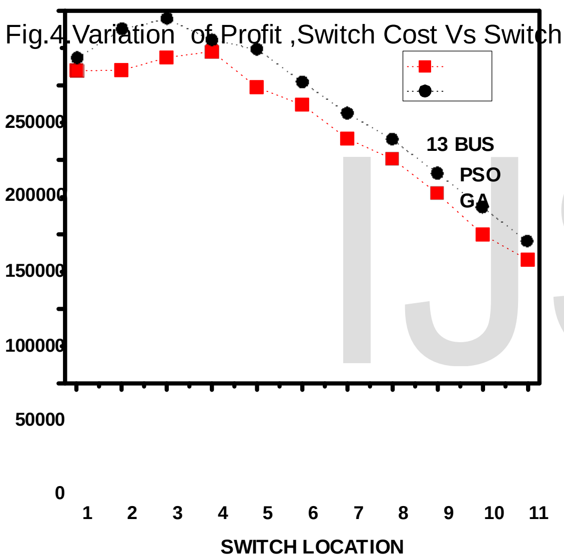


Fig. 5. Profit vs Switch

Table 4

Load Data For 13 Bus System

| No of switch | ENS | SAIDI | Profit (GA) | Profit (PSO) |
|---|---|---|---|---|
| 0 | 122400 | 4.6525 | 0 | 0 |
| 1 | 91875 | 3.6213 | 218600 | 209878 |
| 2 | 87150 | 3.3852 | 238225 | 209994 |
| 3 | 85500 | 3.2838 | 245162 | 218568 |
| 4 | 83500 | 3.2283 | 230663 | 222731 |
| 5 | 81250 | 3.1727 | 224562 | 198637 |
| 6 | 80875 | 3.1271 | 202450 | 186882 |
| 7 | 79775 | 3.1065 | 181300 | 164123 |
| 8 | 79437.5 | 3.0871 | 163650 | 150528 |
| 9 | 79087.5 | 3.0815 | 140750 | 1272220 |
| 10 | 78637.5 | 3.0760 | 117850 | 99721 |
| 11 | 78337.5 | 3.0704 | 94950 | 82761 |

## 4 Results & conclusions

To find out the reliability indices ,customer oriented indices and optimal location of switches to calculate the profit for 13 Bus radial distribution network has been considered .Different optimization technique has been applied to evaluate the problem in order to compare the results. These techniques provides us optimal location of switches in radial distribution system and profit. For 13 Bus system ,the optimal no. of switches is 7.Similarly, for 6 Bus system ,we can use maximum two switches to get optimal profit & minimum SAIDI.

## 5 Future work

Reliability analysis of different loads (domestic load ,commercial load, governmental load ,seasonal load etc),the impact of distributed generated on the optimum location of isolators ,provision of highly sophisticated power electronics devices ,manual devices along with automatic sectionalizing device is made to improve the system reliability etc may be taken into account for future work

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