Multiobjective Elitism based Genetic Algorithm for Service Restoration Planning through Feeder Reconfiguration in Distribution System with DG

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Abstract: *This work intends to foresee an service restoration plan for distribution system with DGs through network reconfiguration. The objectives in the problem formulation are minimizing the out of service area, reducing the number of switching operations, reducing the total network losses along with radial network structure, voltage and current limits are considered as constraints. Rowlett wheel selection process and elitism is used in Genetic Algorithm which gave better optimization results. An efficient algorithm is developed which predicts proper service restoration plan for distribution system planned and unplanned outages.The proposed algorithm is tested on IEEE 33 bus system using MATLAB software.*

Key words: *Genetic algorithm; reconfiguration; service restoration; time varying loads*

1. Introduction

The electric power distribution systems consists of groups of interconnected radial circuits and have a number of constraints like radial configuration, all loads served, coordinated operation of over current protective devices, and voltage drop within limits etc. Each feeder in the distribution system has a different mixture of commercial and industrial type of loads, with daily load variations.Due to uncertainty of system loads on different feeders, which vary from time to time, the operation and control of distribution systems is more complex particularly in the areas where high load density is high. With the development of economy and progress of the society, customers require the power supply more reliable [1,2].

Distribution system is planned in such a way that it supplies the consumers without any longer interruption during an outage condition. Whenever a fault occurs in the system, relays detect the faulted areas and disconnect the network by opening the circuit breakers. During the fault, power becomes unavailable to the loads in certain areas or to the particular customer loads and the power utilities should re-energize the loads as quickly as possible. The re-energizing procedure is called as service restoration.

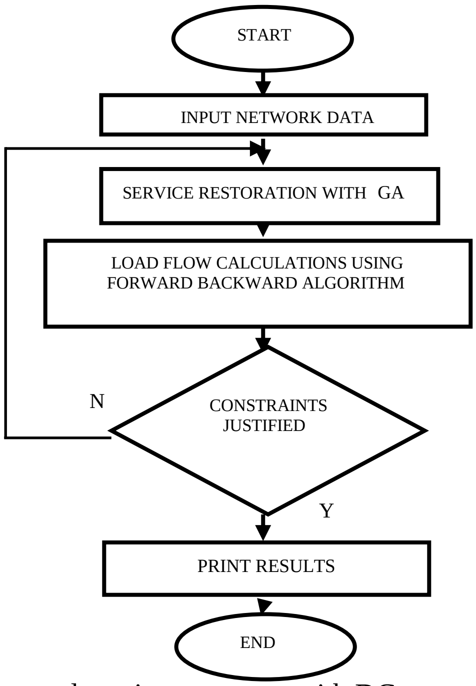
The operators in control centers detect the out-of-service areas and decide the switches to be opened and closed in order to restore the out-of-service areas via feeder reconfiguration [3-5].The integration of Distributed generation to distribution systems poses many challenges to the system operation and control.

An effective post fault supply restoration strategy for distribution networks play a key part in improving service reliability and enhancing customer satisfaction. Generally power distribution network reconfiguration provides service to as many customers as possible following fault and during planned outage for maintenance purposes with system loss minimization and load balancing of the network. It allows the transfer of loads from heavily loaded feeders or transformers to relatively less heavily loaded feeders or transformers. Such transfers are effective in terms of altering the level of loads on the feeders being switched as well as in improving the voltage profile along the feeders and have affecting reduction in the overall system power loss.

Distribution system reconfiguration for loss reduction was first proposed by Merlin et al [6]. They employed a blend of optimization and heuristics to determine the minimal loss operating configuration for the distribution system represented by a spanning tree structure at a Objective function Specific load condition. Since then, many techniques have been proposed. Ref [7] [8] provides a survey of the state of the art in distribution system reconfiguration for system loss reduction. These methods can be classified into two groups (i) Heuristics methods and Mathematical optimization techniques [8-17]. The use of heuristics was justified by the need to reduce the search space of reconfiguration problem. Optimization techniques include linear programming, dynamic programming and simulated annealing (ii) AI based approaches [18-20], including expert systems and neural networks. More recently, Ant colony and genetic algorithms have been proposed for distribution reconfiguration for loss reduction [21, 22]. The results are very encouraging.

Genetic Algorithms are versatile hunt methods that get their models from the hereditary procedure of natural living beings in view of the hypothesis of advancement. GA can be a proficient strategy for taking care of extensive scale combinatorial enhancement issues on the grounds that it can discover worldwide ideal arrangements.The characteristics of genetic algorithms make them particularly suited to ill-structured optimization problems [23-24].This is because GAs use pay-off (fitness or objective function) directly for the search direction, so no mathematical assumption is needed and GA searching from a population of points can discover global optimum very rapidly. However, as discussed in ref [21], Crossover operation has the danger of generating individuals which violate radiality constraints by swapping string of two parent networks. Although techniques can be introduced to get rid of those bad individuals, this will inevitably increase the computation. In addition, the encoding and decoding used in ref [22] are very complicated which slows down the speed of the algorithm.

These drawbacks in the optimization algorithm may cause the reconfiguration for service restoration to go imprecise which could lead to excess total power losses. Therefore, there is a necessity to refine the GA for better optimum results . In some of the works, DGs were not considered in service restoration i.e., actual active Distribution Network is accounted for feeder reconfiguration. In literature a very few works are addressed to achieve the restoration with loss reduction



and bus voltage improvement with DGs.

Fig. 1. Flow chart for Service Restoration with Genetic Algorithm.

Rest of the paper sorted by the following ; the problem formulation of proposed work described in section 2,the suggested techniques approach receive throughout section 3 . Test system and results effects as well as the related discussions given in section 4 as well as section 5 presents conclusions of the work.

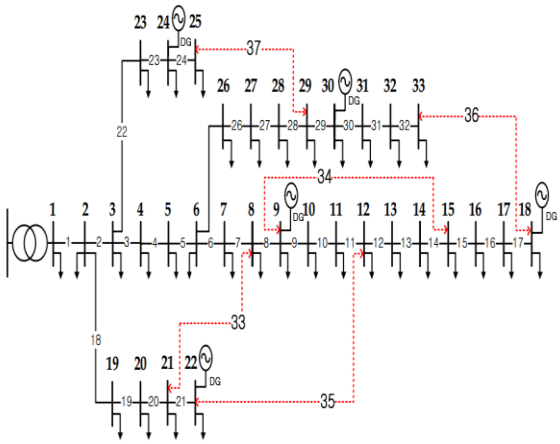
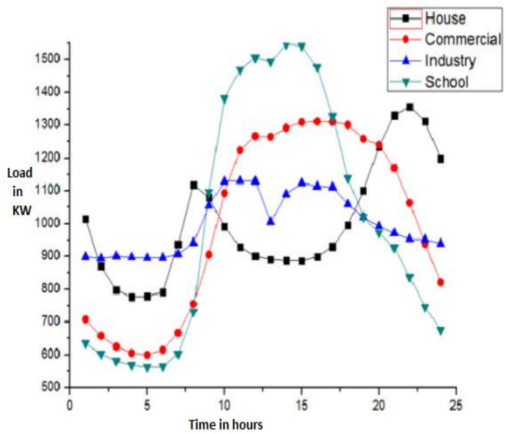


Fig 2. IEEE 33 bus test system



. Fig.3.a) Load curve of different customers

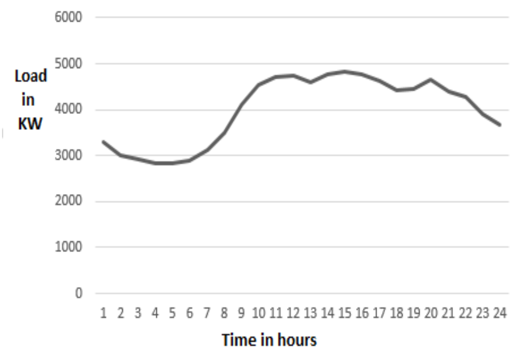


Fig.3 b) load duration curve

Table.1 Location of different customers

Types of customer	Bus number
Residential -R	1 TO 18
Industrial -I	19 TO 22
Commercial- C	23 TO 25
School-S	26 TO 33

Table 2 . Grouping of load hour

Cases	Time/Hours
Case 1	2, 3, 4, 5, 6
Case 2	1, 7, 8, 23, 24
Case 3	9, 18, 19, 21, 22
Case 4	10, 11, 12, 13, 14, 15, 16, 17, 20

Table 3 . Grouping of load hours

Case 1		P (kW)	Q (kvar)	Total Average load
	R	43.66	26.66	2894 +j 1793.41
	I	225	139.5	
	C	77.75	48.29	
	S	195.33	121.33	
Case 2	R	62.22	38.57	3500 +j 2168.95
	I	230.5	142.91	
	C	9952	61.535	
	S	260	161.2	
Case 3	R	6555	40.61	4332 +j 2684
	I	249.5	154.69	
	C	143	88.66	
	S	33667	208.73	
Case 4	R	53.395	33.104	4691 +j 2907
	I	266.67	165.33	
	C	153.47	95.15	
	S	465.56	302.614	

2. Problem formulations

A. Forward /Backword Power flow equations

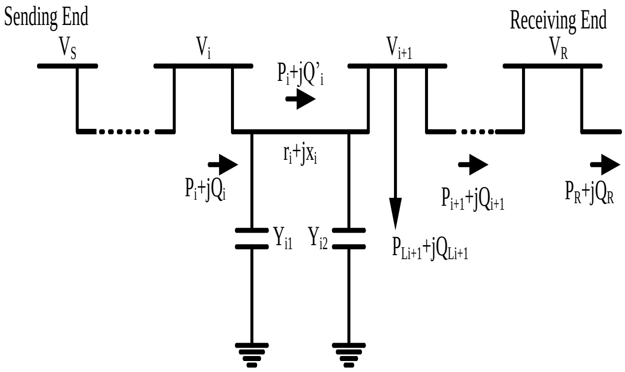


Figure.1: Line diagram of the distribution system

The power flow of the distribution system is estimated from the ensuing set of recursive equations obtained from the single line diagram figure 1 [22].

$$P_{i+1} = P_i - \frac{R_i}{|V_i|^2}\left\{P_i^2 + \left(Q_i + Y_i|V_i|^2\right)^2\right\} - P_{Li+1} \tag{1}$$

$$Q_{i+1} = Q_i - \frac{X_i}{|V_i|^2}\left\{Q_i^2 + \left(Q_i + Y_i|V_i|^2\right)^2\right\} - Y_{i1}|V_i|^2 - Y_{i2}|V_{i+1}|^2 P_{Li+1} - Q_{Li+1} \tag{2}$$

$$|V_{i+1}|^2 = |V_i|^2 + \frac{R_i^2 + X_i^2}{|V_i|^2}\left(P_i^2 + \left(Q_i + Y_i|V_i|^2\right)^2\right) - 2\left(R_iP_i + X_i\left(Q_i + Y_i|V_i|^2\right)\right) \tag{3}$$

The power loss in the line section linking the buses i and $i+1$ may be calculated per Equation (4) shown below:

$$P_L(i, i+1) = \frac{R_i(P_i^2 + Q_i^2)}{|V_i|^2} \tag{4}$$

Where, P_i is the real power flowing out of bus i, Q_i represents the reactive power flowing out of bus i, P_L is the real power loss in the line connecting buses i and $i+1$, P_{Li+1} is the real load power at bus $i+1$, Q_{Li+1} is the reactive load power at bus $i+1$, Y_i is the admittance of bus i, V_i is the voltage at bus, R_i is the resistance of the line section between buses i and $i+1$, X_i is the reactance of the line section between buses i and $i+1$.

The mentioned equations are used for the load flow analysis of the distribution system.There are many criteria depending on the performance of the system for an operator to determine the switch statuses in the distribution system. It is known that network operator hopes the MW losses are minimized if the system is in normal state or after the fault clearance.

B. Objective Functions

i.Minimize the aggregate losses in the framework

$$\text{Min } (\bar{V}, \bar{X}) \quad (5)$$

iii.Minimize the number of switching operations

$$\text{Min} f_2(\bar{X}) = \sum_{i=1}^{N_S} |S_i - S_{0i}| \quad (6)$$

Where, '$\bar{V}$' is the vector of voltage magnitudes of the different buses,"$\bar{X}$ " is the vector of the switches status. F ($\bar{V}$, $\bar{X}$) is the active power loss. Where $\bar{X}$ denotes the switch state vector, i.e. $\bar{X}$ = [S_1, S_2, S_3 . . . . S_{Ns}] represents to the aggregate switch number of the considered framework and is the status of switch (0 and 1 speak to

the opened and closed status, separately). S_{0i} represents the state of switch i (after the fault is isolated).

C. Constraints

A radial network structure must remain after service restoration. To maintain a radial network configuration, the proposed solution algorithm contains the following switching operational sequences.

1) The switch (as an isolating or sectionalizing switch) to be opened is operated first.

2) If the radial structure is violated after closing a switch, this switch cannot be selected as a backup switch. That will cause a feeder with two power supplies from both sides.

3) If inter-loops are still generated after the above steps, one switch in the loop must be arbitrarily opened.

3. Genetic algorithm

Among the methods which can give us a global optimal solution is GA. Genetic algorithms use the principle of natural evolution and population genetics to search and arrive at a high quality near global solution. Due to the nature of the reconfiguration design variables (Switches status), The required design variables are encoded into a binary string as a set of genes corresponding to chromosomes in biological systems.Unlike the traditional optimization techniques that require one starting solution, GA uses a set of chromosomes as initial solutions. The group of chromosomes is called a population. The merit of a string is judged by the fitness function, which is derived from the objective function and is used in successive genetic operations. During each iterative procedure (referred to as generation), a new set of strings with improved performance is generated using three GA operators (namely reproduction, crossover and mutation) [23].

A. Initial population

In this stage, the network data (given Table I) is entered and the genetic algorithm program generates different random solutions which present different status for the switches. Fig. 1 gives an example of a single random solution presented by a chromosome with binary genes. Accordingly, a different network configuration is randomly initiated.

B. Objective and Fitness functions

Based on the initial random configurations, the objective function and the penalty function composed of the constraints and bounds are calculated. The fitness function of each solution is then calculated as follows

$$\text{Fitness function} = \frac{1}{f(V,X) + penalty(V,X) + \varepsilon} \quad (7)$$

Where ε is the tolerance to avoid division by zero. The strings are stored according to their fitness which is then ranked accordingly.The roulette wheel selection scheme is used for selecting the individuals for reproduction.

The most important components in a GA consist of

- Representation (definition of individuals)
- Evaluation function (or fitness function)
- Population
- Parent selection mechanism
- Variation operators (crossover and mutation)
- Survivor selection mechanism (replacement)

C. Genetic operators

Genetic operators are the stochastic transition rules applied to each chromosome during each generation procedure to generate a new improved population from the previous one. A genetic algorithm usually consists of reproduction, crossover and mutation operators.

i) Reproduction/ Selection

Reproduction is a probabilistic process for selecting two parent strings from the population of strings on different basis. In this paper the "roulette-wheel" mechanism is used on the individual fitness values. This ensures that the probability of a string to be selected is proportional to its fitness relative to the rest of the population. Therefore, strings with higher fitness values have a higher probability of contributing offspring.

ii) Crossover

Crossover is the process of selecting a random position in the parents' strings and swapping the characters either left or right of this point with each other. This random position is called the crossover point. In this paper the characters to the right of a crossover point are swapped. The probability of parent-chromosomes crossover is assumed to be 0.8. .

iii) Mutation

Mutation is the process of random modification of a string position by changing "0" to "1" or vice versa, with a small probability. It prevents complete loss of genetic through reproduction and crossover by ensuring that the probability of searching any region in the problem space is never zero[23]. In this paper the probability of mutation is assumed to be 0.02.

iv) Elitism

Crossover and mutation may destroy the best solution of the population pool. Elitism is the preservation of few best solutions of the population pool. It is defined in percentage or real number.

3.1 Genetic Algorithm for supply restoration problem

Application of Genetic algorithm to Service Restoration problem is described below.

String Encoding

The main requirement for applying a GA to an optimization problem is the existence of a coding that maps for all possible solutions to chromosomes as possible to feasible solutions. The ideal encoding is one that gives only feasible solutions and the GA would then only need to find the optimum solution.

In the case of the supply restoration problem, the solutions that must be encoded are the sets of the switch states of the network, since distribution network topology can be uniquely defined by the combination of status of all available switches. The most natural coding method is to have a binary string with length equal to the number of switches on the network. Each switch state is represented by one bit with value '1' or '0' corresponding to 'closed' or 'open'. This encoding, however is a poor choice because it does not force the chromosome to generate a feasible solution.

The encoding proposed here is that of integer permutation. In an integer permutation encoding, the genes are the integers from one up to the number of positions. The solution that the chromosome defines depends on the relative ordering of the integers.For the supply restoration problem, each integer in the permutation will be an index into a list of switches that can be used for restoring the supply. The integers therefore have values from one to the number of switches need to be investigated. It is noted if there are K integers with values from 1 to k, to represent k different switches. The sequence of these integers represent an ordered operation sequence of switches to be followed to generate a valid network topology. For instance, for a system with six switches considered for supply restoration, a string of length six: (3 2 6 5 1 4) defines an ordered switch sequence: Switch 3, Switch2, Switch6, Switch1 and finally Switch 4.It has been mentioned before that the GA itself has no knowledge about the problem. So the string has shown above is only a permutation of switches. In order for the string to be meaningful and map a valid network topology suitable for supply restoration, these switches must be assigned status values either as 'closed' or 'open' subject to the radiality constraint of the distribution network. Here a scheme based on graph theory is proposed to decide the status of these switches.

String Interpretation

Before the GA begins, the actual distribution network will be mapped to a graph. The branches of the graph will correspond to the switches that can be operated for supply restoration while the nodes have the graph will represent all the elements of the network that do not include any of these switches. That is, each node will represent in an island of the network that cannot be reduced to two smaller islands.

Initially all switches are assumed to be open. Starting with the first integer in the chromosome the corresponding switch is closed. The process is repeated for each next integer until the end of the chromosome is reached. If closing a switch would violate certain constraints such as creating loops or connecting sources then that switch operation is abandoned. And the next integer in the chromosome is considered.

To test for loop and source connection violations each node of the graph will initially be assigned a unique colour value (represented a positive integer), expecting those nodes that contain generators or infeeds (considered as source nodes) which will be assigned the same colour value of '0'. All the branches will be removed to represent a network with all switches open. Each branch will be visited in the order determined by the chromosomes. If a visited branch connects two nodes of different colour then it will be inserted into the graph and all nodes having the higher colour of the two will be changed to have the lower colour. Preventing two nodes of the same colour being connected guarantees that loops are avoided, and assigning the same colour to all source nodes ensures that two sources will never be connected together. At the end of this procedure the switches in the network that have their corresponding branches inserted in the graph will be closed and all the other switches will be open, thus generating the set of switch states corresponding to a new one.

If there are k switches in the network, and N nodes in the graph, the problem is to connect the N nodes with an ordered series of a subset of (or all of) the k switches, which is an integer permutation. The sequence order is important since it contains information to guide the search path to unvisited nodes. With a chromosome of the form: (I1, I2, I3……Ik)
Where, 1<=Ii<=K and Ii is not equal to Ij for i not equal to j. Owing to the fact that all switches are in open position, at the beginning. Switch on these switches in the sequence order: Switch (I1)-Switch (I2)-……Switch (Ik) until it reaches the end of the chromosome.

Before executing this process, each of the N nodes in the graph will be assigned an integer which is refered to as colour. If there are N_s source nodes in the network, they will be assigned to the same colour ‘0’, while each of the non-source nodes will be assigned to a unique integer value from 1 to $(N – N_s)$. The operation status of every switch will be decided by the constrained scheme to avoid loops and direct connection of two sources. This branch insertion scheme guarantees that the final switch permutation will be equivalent to a valid network configuration which is a radial network consisting of N_s spanning trees rooted at the N_s source nodes of the network. If a precursor symbol ‘+’ denotes the switch state is ‘open’, while ‘-‘ denotes the switch state to be ‘closed’, the initial string can be denoted by: $(+I_1 + I_2 + I_3 + \ldots\ldots +I_k)$, Where all switches are in ‘open’ states. The final reached switch permutation will be of the form: $(-I_1 (+ -) I_2 (+ -) I_3 (+ -) \ldots\ldots (+ -) I_k)$ Where (+ -) denotes either the ‘open’ or ‘closed’ state according to the graph constraints.

3.2 Steps for proposed algorithm

The proposed algorithmic steps for solving Network reconfiguration can be summarized as follows.

Step 1: Read the bus data, line data, and switch data, etc.

Step 2: Estimate the population size, crossover rate, and mutation rate for the GA. The initial chromosomes encoded by the Prufer number are randomly selected. The length of each chromosome is the number of switches available in the network. Each bit in the chromosome indicates the status of the switch. (‘0’ means that switch is opened. ‘1’means that switch is closed.).

Step 3: This chromosomes are encoded into the prufer number. N is the number of buses, If the length of the prufer number is N-2, then the network corresponding to that coded chromosome is radial. If the length of the chromosome is less than or more than N-2, the network, corresponding to that coded chromosome is not radial These chromosomes are converted into the radial configuration and then added to the population for further process.

Step 4: Compute the load flow calculation for each chromosome using backward sweeping method. From this load flow calculation, the bus voltages, line current through all the lines, real and reactive power losses on the each line can be easily computed for each chromosome.

Step 5: If inequality constraints are violated, the penalty function is augmented to the fitness function (the negative objective for maximization).

Fitness = 1/objective function for minimization function.

Step 6: Rowlett wheel selection approach is used to reproduce new offspring.

Step 7: If all the new chromosomes are the same (convergent), then stop. Otherwise go to the next step.

Step 8: Perform crossover and mutation operations in GA.

Step 9: Go to Step 3.

4. Test system and simulation results

In this work, a speculative 11kV radial distribution test framework with 33 buses and aggregate load of 3.595 MW , P type DG (PV type) each of 100 kW of 5 numbers are connected at 9,18,22,24,30th shown in fig. 2 [30]. The buses comprise of commercial, house, industry and school and all the diverse kind of burdens are scattered to every transport. A high extent of DG limit will cut down the force quality. Henceforth, the aggregate limit of PV does not more than 25% of the aggregate framework limit in the test framework.The simulation is carried out on IEEE 33 bus test system using MATLAB R2009a software.

Load curve data consist of four categories of loads ie Residential, Industrial, commercial and school and corresponding load duration curve shown in fig.3(a) and (b) respectively. The load hours are divided into four cases where in each case consists of approximately similar load patterns in a given period of time. The details of different type of consumer buses and division of daily load curve into four cases are shown in Table 1 and Table 2 respectively

Table 4. Service restoration plan results [27]

Fault Branch	Switch pattern		Power Loss (kW)	No. of Sw. Opera-tion
	Sw. Open	Sw. Closed		
3	3,27,3	35,36 ,37	330	6
9	9,13	34,35	180	4
10	10,12	34,35,37	180	4
14	14,29	34,36	290	4
15	21,26	35,36,37	190	4
17	17,8	35,36	170	4

Table 5 Proposed service restoration plan

Fault Branch	Switch pattern		Min. voltage pu	Power Loss (kW)	No. of Sw. operation
	Sw. Open	Sw. Close			
3	17, 30	33,36, 37	0.9542	90.36	5
9	30	34, 36	0.9585	51.98	3
10	10	34, 36	0.9524	195.74	3
14	32	34, 36	0.9557	268.89	3
15	13	34, 36	0.9548	179.79	3
17	17	34, 36	0.9507	172.87	3

Proposed algorithm are tested with and without DG system for the following cases:

Scenario : Service restoration plan with system load[30]

Scenario :Service restoration for time varying load shown in fig.3.a

Service Restoration plan without DG

The service restoration scheme for IEEE 33 bus test system carried out for two load patterns . Intially without time varying loads and in the absence of Distributed Generation, is given in Table 5.Fault is simulated at some particular branches and the corresponding switching pattern for restoration is obtained from algorithm. This analysis can be extended to predict the switching patterns to restore the loads following fault in any branch of the network.

Table 5. shows results the switching pattern i.e. the switches to be closed and switches to be opened to restore the service back to customers, total network loss, minimum voltage, and number of switching operations after service for restoration.

Table 6. Restoration plan with time varying loads and DG

Fault Branch	Switch pattern		Min. voltage pu	Power Loss (kW)	No. of sw. opera tions
	Sw. Open	Sw. Closed			
3	3, 1	33, 36	0.9686	78.63	4
9	9, 32	34, 36	0.9701	47.43	4
10	10, 5	34, 33	0.9694	163.48	4
14	14, 15	34, 36	0.9723	249.74	4
15	15, 36	34, 36	0.9781	170.08	4
17	17	36	0.9632	166.45	2

The obtained results compared with the results of paper [27] shown in Table 4. From Table 5, it is observed that, all the unserved loads are restored back with quality power supply which is reflected in the parameter minimum voltage.The numbers of switching operations are also minimized. Further losses in all fault cases significantly reduced and number of switching operation are also reduced.

Ths simulation is carried out with DG in system and the corresponding results shown in Table.6. It is observed that, voltage profile is improved from 0.9542 pu to 0.9686 pu , losses 90.36 kW reduced to 78.63 kW and number of switching operation 5 to 4 when fault at branch 3. The rest of the results also shows the improvement over the without DG case.

Service Restoration plan with time varying load

The PV type DG are considered where only real power injection is present and there is no reactive power injection.

Four different cases are studied with time varying loads and predict the switching patterns for service restoration through reconfiguration following a fault to meet the objectives and satisfy the constraints.The result summary includes the switching patterns without DG and with DG.

Table 8. Demonstrates the GA execution parameters for the proposed algorithm. The restoration plan in all the cases restore the power back to the out of service regions while satisfying the defined objectives and limitations.

The fault is simulated at branch no. 2 and corresponding results tabulated in Table 8 and Table 9 shows the service restoration scheme without and with DG respectively. The loads associated with all the buses in system restored the power back with open and closing of sectionalising switches after fault condition. Comparison results without and with DG when fault at branch 2 shown in fig.4 and fig .5. From the results, it is observed that and improvement in minimum voltage in system and 16.29,18.12,51.10 and 37.42 % power loss reduced with DG consideration in 1,2,3 and 4 case respectively.

Fault at branch 9 is additionally recreated and restoration plan without and with DG results are arranged in Table 10 and Table 11. Voltage increased from 0.9693 to 0.9846 , 0.9746 to 0.9801, 0.9702 to 0.9726 and 0.09642 to 0.9642 in 1,2,3 and 4 cases respectively ensures the bus voltage lies within the envelop.

Table 7. Service restoration plan without DG

Fault at branch 2.	Switch pattern		Power losses (kW)	Min . voltage pu
	Open	close		
Case 1	2,26	33,37	168.86	0.9601
Case2	2,22	33,37	149.7	0.9626
Case 3	2,29	33,36	198.62	0.9583
Case 4	2,9	33,34	172.30	0.9518

Table 8. Genetic algorithm performance parameters

Population size	20
Chromosomes length	38 -equal to number of switches
Mutation rate	0.2
Selection rate	05
Crossover probability	0.85
Elitism	0.1
Maximum iteration	1000

Table 9. Restoration plan with DG

Fault at branch 2.	Switch pattern		Power losses (kW)	Min . voltage pu
	Open	close		
Case 1	2	35	141.34	0.9784
Case2	2,22	35,37	122.56	0.9708
Case 3	2,5	35,36	97.12	0.9686
Case 4	2,10	35,33	101.85	0.9593

Table 10. Service Restoration plan without DG

Fault at branch 9.	Switch pattern		Power losses (kW)	Min. voltage pu
	Open	close		
Case 1	9,5	33,34	110.86	0.9693
Case2	9,5	35,37	103.70	0.9746
Case 3	9,16	34,36	138.62	0.9702
Case 4	2,10	34,36	121.30	0.9642

Table 11. Service Restoration plan with DG

Fault at branch 9	Switch pattern		Power losses (kW)	Min. voltage pu
	open	close		
Case 1	9	34	95.68	0.9846
Case2	9,26	35,37	87.42	0.9801
Case 3	9,5	33,36	111.64	0.9726
Case 4	9,5	35,37	107.42	0.9710

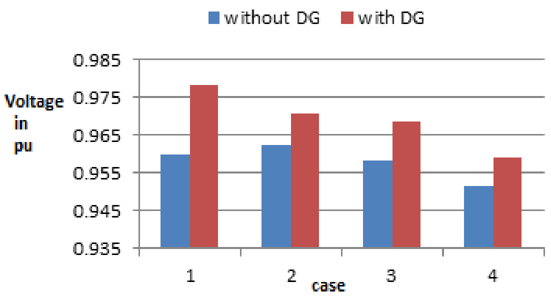


Fig. 4. Voltage profiles after reconfiguration for time varying load cases with and without DG

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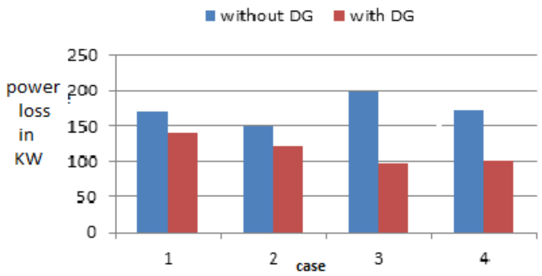

Fig. 5. Total power loss after reconfiguration for time varying load cases with and without DG

5. Conclusion

Service restoration plays an important role in maintaining continuous and quality power supply to the connected customers. It will greatly reduce the cost of interruption due to the loss of power following an outage. This work provides an optimum restoration plan for distribution systems following any unplanned outages due to faults and planned outages for maintenance purpose. The obtained results are compared with previous works and improvements are observed in loss minimization , voltage and reduction in switching operations.

The restoration plan in the presence of DG shows that, better voltage levels could be obtained in the presence of DG and losses are further minimized. The work emphasizes not only on restoring the power back to the consumers but also to satisfy the objectives such as minimizing the total network losses, reducing switching operations there by reducing the deterioration of switches, switching losses and reducing the voltage deviation.

References

1. T. Thakur and Jaswanti. :"*Study and Characterization of Power Distribution Network Reconfiguration*" .IEEE PES Transmission and Distribution Conference and exposition vol.-16,2012 , no. 2, p. 1-6.
2. W. Wei, M. Sun, R. Ren, and Y. Wang.: *"Service restoration of distribution system with priority customers and distributed generation"*. Innov. Smart Grid Technol. - Asia, 2012 IEEE, p. 1–6, 2012.
3. X. Chen, D. Chen, J. Liu, Y. Liao, K. Yu, and H. Hu.: *"Fast service restoration of distribution system with distributed generations"*.IEEE Power Energy Soc. Gen. Meet., 2012,p. 1–6.
4. M.R. Irving,W.P.Luan, J.S.Daniel.:*"Supply restoration in Distribution Networks using Genetic Algorithm"*. International Journal of Electrical Power & Energy Systems , Volume -24.2002, p. 447-457.
5. Yogendra Kumar, Biswarup Das.: *" Multiobjective, Multiconstraint Service Restoration of Electric Power Distribution System With Priority Customers" . IEEE Transactions on Power Delivery*, Vol. 23, 2008, p.261-270.
6. N.Shanmuga Vadivoo, S.Mary Raja Slochanal. : "*Distribution System Restoration Using Genetic Algorithm with Distributed Generation"*. In: *CSSENET Modern Applied Science Journal* , Vol 3. No.4, 2009
7. Wei, Mingjun Sun, Ran Ren, Youn Wang.: " *Service Restoration of Distribution System with Priority cust -omer and Distributed Generation"*. IEEE Innovative Smart Grid Technologies - Asia, ISGT ,21-24 May 2012p.1 – 6
8. R. J. Sarfi, M.M. Salama, A. Y. Chikhani.: "*A survey of the state of the art in distribution system reconfiguration for system loss reduction"*. Electric Power Systems Research, 1994, p .61-70
9. T. Taylor and D. Lubkeman.: "*Implementation of heuristic search strategies for distribution feeder reconfiguration"*. IEEE Transactions on Power Delivery, Vol. 5, 1990, p. 239-246.
10. T. P. Wagner, A. Y. Chikhani and R. Hackam.: "*Feeder reconfiguration for loss reduction: An application of distribution automation"*.IEEE Transactions on Power Delivery, Vol. 6, No. 4, Oct. 1991, p. 1922-1931.
11. S. Civanlar, J. J. Grainger, H. Yin and S. S. H. Lee.: "*Distribution reconfiguration for loss reduction",* IEEE Transactions on Power Delivery,Vol. 3, 1988, p. 1217-1223.
12 Mesut E. Baran and Felix F. Wu.: "*Network reconfigur -ation in distribution systems for loss reduction and load balancing"*.IEEE Transactions on Power delivery, Vol. 4, No. 2, April 1989, p. 1401- 1407.
13. P. Verho, P. Jarventausta, M. karenlampi and J.Partan -en.: "'*Reducing the operation costs of a distribution network via reconfiguration"*. In: IEEE/ KTH Stockholm Power Tech Conference, Stockholm, Sweden, June 18-22,1995,p. 264-269.
14. G. J. Peponis M. P. Papadopoulos and N. D.Hatziar -gyriou.:"*Distriution network reconfiguration to min -imize resistive line losses"*. IEEE Transactions on Power Delivery, Vol. 10, No.3,July 1995, p. 1338-1342.

15. C. C. Liu, S. J. Lee, K. Vu.: " *Loss minimization of distribution feeders: optimality and algorithms".* In: IEEE Trans Power Delivery, 1989, p.1492-1498.

16. H. D. Change, R. Jean-Jumeu.: " *Optimal network reconfigurationsin distribution systems, Part I and Part II.* In: IEEE Trans Power Delivery, 1990, p.1902-1909.
17. Hong-Chan Chang and Cheng-ChienKuo.: " *Network reconfiguration in distribution systems using simul -ated annealing".* In:Electric Power Systems Resear -ch , 29(1994), p. 227-238.
18. Sakae Toune, Hiroyuki Fudo.: *"Comparative Study of Modern Heuristic Algorithms to Service Restoration in Distribution System".* In :IEEE Transactions on Power Delivery, vol.17,2002, no.1,p.173-181.
19. G. Chang, J. Zrida, J. D. Birdwell.: " *Knowledge-based distribution system analysis and reconfiguration".*IEEE Trans Power Syst., 1990, p.239- 246.
20. Derrick Bouchard and Aziz Chikhani, V. I. John and M. M. A. Salama.: "*Applications of Hopfield neural networks to distribution feederreconfiguration"*, Proceedings of the Second International Forum on Applications of Neural Networks to Power Systems*".*April 1993,Yokohama, Japan, p. 311-316.
21. Hoyong Kim, Yunseok KO and Kyung-Hee Jung.: "*Artificial neural-network based feeder reconfiguration for loss reduction in distribution systems".*IEEE Transactions on Power Delivery, Vol. 8, No. 3 July1993, p. 1357-1367.
22. Jaydeep Chakravorty, "*Network Reconfiguration of Distribution System Using Fuzzy Controlled Evolutionary Programming*", International Journal of Engineering Science & Advanced Technology, Vol.2, No.2, 2012, p.176-182
23. Ching-Tzong Su, Chung-Fu Chang and Ji-PyngChiou.: *Distribution network reconfiguration for loss reduction by ant colony search algorithm".* Electric Power Systems Research, Vol. 75, Issues 22, August 2005,p. 190-199.
24. N.C. Sahoo and K. Prasad.: "*A fuzzy genetic approach for network reconfiguration to enhance voltage stability in radial distribution systems*".Energy Conversion and Management, Vol. 47, Issues 18-19, Nov. 2006,p. 3288-3306.
25. F. Li, Y. H. Song, R. Morgan, D. T. Cheng.: " *Genetic algorithms in electric power system optimization*". Proceedings of Adaptive Computing in Engineering Design and Control, 1994, p. 77-83.
26. Nara K, Shiose K kitagawa M ,Ishihara T. "*Interrupt - ion of GA for DS for minimum configuration ",* In: IEEE Transaction on power system 1992 :7(3), p.1044-51
27. Y. Fukuyama, H. D. Chiang, "*Parallel genetic algorithm for service restoration in electric power distribution systems".* Electric Power & Energy Systems. vol. 18, no. 2, 1996, p. 111-119.
28. N.Shanmuga Vadivoo, S.Mary Raja Slochanal. : *"Distribution System Restoration Using Genetic Algorithm with Distributed Generation".* In: *CSSENET Modern Applied Science Journal* , Vol 3. No.4, 2009.
29. Ying-Tung Hsiao, Ching-Yang Chien.:*"Enhancement of Restoration Service in Distribution Systems using Combination Fuzzy-GA Method",* IEEE Transaction on Power Systems, vol. 15, no. 4,2000, p.1394-1400.
30. Bohyeon Cho, KihwanRyn, Jinhyan Park, Wonsik Moon, Sungmin Cho .: *" A selecting method of optimal load on time varying distribution system for Network reconfiguration considering DG".* ICEE ,vol 2 ,2012, p,166-170.
31. Aashish kumar bohre1 , Dr. Gang agnihotri Dr.Mani s-ha dube *"Distributed generation planning includi ng load models using different optimization techniques"* Journal of Electrical Engineering, Volume-16,2016 , edition -1,p-171.

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