



## Analysis of Crowding Population Based Ant Colony Optimization for Service Restoration Problem in Distribution System

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**Abstract:** The crowding population based ant colony optimization algorithm (CP-ACO) uses a different pheromone update in comparison to other ACO algorithms. In this paper, crowding population based ant colony optimization algorithm is proposed to solve service restoration problem. The most notable achievement featured in this paper is run time reduction of algorithm to solve the service restoration task. The results on three test systems show the prominent efficiency of CP-ACO algorithm.

**Keywords:** Non dominated sorting; crowding population based ant colony optimization; priority customers; service restoration

### I. INTRODUCTION

To maintain the customer satisfaction and the consequent revenue earned by the power distribution company, fast restoration of power supply to the healthy out-of-service area is of profound importance. However, in the course of service restoration, several related issues must also be considered as: (1) The power supply must be restored to the maximum possible healthy out-of-service area. (2) From economic point of view, there should be minimum loss in the system after the service restoration is accomplished. (3) Radial topology of the distribution systems should be maintained. (4) To maintain the safety and security of different power system components (such as transformers and lines etc.), it is important that the bus voltages and line currents should not cross their respective operational limits. (5) Number of switch operation should be minimum for service restoration to reduce time taken in the service restoration process. (6) In the event of partial service restoration, the supply must be restored to highest priority customers and this fact should be reflected in the final solution of service restoration problem. (7) The software run time required by the service restoration algorithm should be minimum for speedier solution. Because of the importance of the service restoration problem, there has been considerable interest in the past in developing suitable methods for service restoration in distribution systems.

To reduce the out of service area as efficiently as possible and the burden of operators, a computer aided decision supports assist the operators. The researchers have developed many methods to solve the service restoration

problem in distribution systems [1]-[10]. In recent years, modern intelligent calculation methods have been also applied in distribution network service restoration such as genetic algorithm (GA) and ant colony optimization (ACO). In conventional GA based techniques [11]-[16] proposed for service restoration, multi objective optimization problem is converted into a single objective function.

The improved technique using GA is Advanced NSGA-II [17] where for solving the service restoration problem, the multi objective nature of the problem is retained without the need for any tunable weights or parameters. But due to radial operation of distribution network, GA based on binary code generates a lot of infeasible solution in the evolutionary process and memory space required is very high. In standard ACO based techniques [22] for solving service restoration [18-21], the multi-objective nature of the problem is converted to a single objective by the use of weighting factors hence multiobjective nature of the problem is not retained finally.

In this paper the authors solved the service restoration problem using crowding population based ACO algorithm [26-28] which has slight advancement in population based ACO [23-25] and is based on Non dominated Sorting Genetic Algorithm[30] with feedback mechanism. It uses different pheromone update rule as in standard ACO and has no evaporation of pheromone. During the optimization process of CP-ACO, there is high probability of generation of better solution at every iteration. The string solution is represented by status of switches. In this work, ants search the best string of binary bits from the generated population based on feedback mechanism of ACO which helps in selection of parents for next genetic crossover. Due to

pheromone update based on integer ranking of different fronts in the entire population of solutions of parents and offsprings, elitism is maintained and convergence is achieved in short time than NSGA-II and conventional GA. Multiobjective nature of the problem is also retained without the use of tunable weighting factors. As a result the proposed methodology is generalized enough to be applicable to any power distribution network. The applicability of proposed methodology has been demonstrated through detailed simulation studies on three different distribution test systems. The paper is organized as follows. In section II, the detailed mathematical description of the service restoration problem is described in detailed. In section III, the salient features of the CP-ACO algorithm is discussed. In section IV, the application of CP-ACO is described in detail and the main results of this work are discussed in section V. Finally section VI presents main conclusions of this paper.

**II. PROBLEM FORMULATION**

In this paper, the service restoration problem has been formulated as a multi-objective, multi-constrained combinatorial optimization problem. The various formulations for objective functions and constraints developed in this work are described as follows:

**A. Objective Functions:**

**a. Minimization of Out of Service Area:**

$$\text{Min } f_1(\bar{X}) = \sum_{i=1}^{b1} L_i - \sum_{i \in B} L_i \quad (1)$$

$\bar{X}$  is switch state vector of network under consideration for service restoration, i.e.  $\bar{X} = [SW_1, SW_2, \dots, SW_{N_s}]$

$SW_j$  = Status of  $j^{th}$  switch. A closed switch is represented by 1 and an open switch is represented by 0.

$N_s$  = Total number of switches in the network.

$b1$  = No. of energized buses in the network before fault.

$L_i$  = load on  $i^{th}$  bus.

$B$  : Set of energized buses in the restored network.

In eqn. (1), it is assumed that in a ‘n’ bus power system, the buses are numbered from 1 to n and in the pre-fault case, all the buses in the network are energized. Therefore ‘b1’ is equal to ‘n’. However, in the post fault scenario, all the buses would not be necessarily energized. Hence, ‘B’ would contain only the energized buses

**b. Minimization of number of manually controlled switch operation:**

$$\text{min } F_2(\bar{X}) = \sum_{j=1}^{N_m} |SWM_j - SWMR_j| \quad (2)$$

Where,  $N_m$  is number of manually controlled switches.

$SWM_j$  = Status of  $j^{th}$  manually controlled switch in network just after fault.

$SWMR_j$  = Status of  $j^{th}$  manually controlled switch in the restored network.

**c. Minimization of number of remotely controlled switch operation:**

$$\text{min } F_3(\bar{X}) = \sum_{j=1}^{N_a} |SWA_j - SWAR_j| \quad (3)$$

Where,  $N_a$  is number of remotely controlled switches.

$SWA_j$  = Status of  $j^{th}$  remotely controlled switch in network just after fault.

$SWAR_j$  = Status of  $j^{th}$  remotely controlled switch in the restored network.

**d. Minimize the losses:**

$\text{min } F_4(\bar{X})$  = Power loss in the restored network which can be calculated with help of load flow. (4)

**B. Constraints:**

a. Radial network structure should be maintained.

b. Bus voltage limits should not be violated.

$$V_{min} < V_j < V_{max} \quad \dots(5)$$

$V_{min}$  = Minimum acceptable bus voltage.

$V_j$  = Voltage at  $j^{th}$  bus.

$V_{max}$  = Maximum acceptable bus voltage.

c. Feeder line current limits should not be violated.

$$I_{min} < I_j < I_{max} \quad \dots(6)$$

$I_{min}$  = minimum acceptable line current.

$I_j$  = Current in  $j^{th}$  line.

$I_{max}$  = maximum acceptable line current.

d. Higher priority customers should always be supplied.

In this paper, solution is based on ranking of objectives. As the customer’s satisfaction is mostly affected by availability of supply, the first objective function (out of service area) has been kept at the first preference. Moreover to achieve restoration plan in short time should be minimum. Now generally the time taken for operating the manually controlled switch is significantly higher (1200-1500 seconds) in comparison to remotely controlled switches (50-60 seconds). Therefore, between any two solutions, the solution which require fewer manual switch operations would require lesser time to achieve service restoration task compared to other solution. As a result the objective function of minimization of number of manually controlled switch operation has been kept at second preference and that of minimization of remotely controlled switch operations has been kept at the third preference. Finally, the objective function of minimization of losses has been kept at the fourth preference.

### III. METHODOLOGY

#### A. Crowding Population Based Ant Colony Optimization:

The Crowding Population-based ACO algorithm (CPACO) was first defined and applied for TSP [26-28] and has slight improvement in population based and colony optimization developed by Guntch and Middendorf [23-25] for dynamic combinatorial optimization problems. CPACO uses a crowding replacement scheme similar to restricted tournament selection. With this scheme a single population (P) of preset size is maintained, which is initialized with randomly generated solutions. All solutions in the population are assigned an integer rank according to the dominance ranking procedure used by the NSGA-II algorithm developed by Deb [30] All elements in the pheromone matrix are initialized to some initial value ( $\tau_{init}$ ).

All solutions in the population increment their corresponding elements in the pheromone matrix according to the inverse of their rank  $\Delta$  i.e.  $\tau_{ij}^s = 1/(S_{rank})$  and is calculated in each iteration.

CPACO uses a single pheromone matrix [27] with individual heuristic matrices for different objective unlike PACO which uses individual pheromone and heuristic matrix for each objective.

CP-ACO assigns each ant a set of unique heuristic exponent correction factors ( $\lambda$ ), similar to the procedure explained in [29] in place of average rank weight method used in P-ACO. This allows each ant to exploit heuristic matrices by different amounts while still using a common pheromone matrix. The transition probabilities are calculated using (7) where  $h$  defines the number of objectives.

$$P_{ij}^k(t) = \frac{[\tau_{ij}(t)] \cdot \prod_{d=1}^h [\eta_{ij}^d]^{\lambda_d \beta}}{\sum_{l \in N_i^k} [\tau_{ij}(t)] \cdot \prod_{d=1}^h [\eta_{ij}^d]^{\lambda_d \beta}} \quad (7)$$

#### B. CP-ACO Algorithm:

The step-by-step procedure of CP-ACO for is described here. The basic algorithm is as follows

- Initially a random population  $P_0$  of size  $N$  is created where  $N$  is the number of strings in the population. The length of each string is equal to the number of bits in each string. Each solution is assigned initial pheromone value  $\tau_i = \tau_{init}$  ( $\tau_{init} > 0$ )
- Create offspring population  $Q_0$  of size  $N$  by applying GA operators i.e. selection, crossover and mutation on  $P_0$ . Here selection will be based on transition probability principle of ant colony algorithm given by equation (7).
- Assign  $P_t = P_0$  and  $Q_t = Q_0$  where  $P_t$  and  $Q_t$  denote the parent and offspring population at any general " $t^{th}$ " generation respectively.
- Create a combined population  $R_t = P_t \cup Q_t$ . Thus the size of  $R_t$  is  $2N$ .
- Perform nondominated sorting on  $R_t$  which divides the population in various fronts. The solution in  $R_t$ , which

do not constrained dominate each other but constrained dominate other solutions of  $R_t$ , are kept in first front and ranked one.. Among the remaining solutions not in rank one which do not constrained dominate each other but constrained dominate all other solutions are kept in second front and are ranked 2. In the similar way all remaining solutions are ranked by integer and is repeated until there is no solution in  $R_t$ .

- To create parent population in next " $(t+1)^{th}$ " generation  $P_{t+1}$ , the following procedure is opted. Initially the rank one front is considered. If the no of solutions ranked one is less than  $N$  then all the solutions of rank one are included in  $P_{t+1}$ . The remaining solution in  $P_{t+1}$  are filled with the solutions from rank 2, 3, 4 and more. This process is repeated until the total no of solutions (i.e  $n$ ) in  $P_{t+1}$  is greater than  $N$ . To make the size  $P_{t+1}$  exactly equal to  $N$ ,  $(n-N)$  solutions from the last included nondominated front are discarded from  $P_{t+1}$ . To choose the solutions to be discarded, initially the solutions of the last included nondominated front are sorted according to their crowding distances and, subsequently, the solutions having least  $(n-N)$  crowding distances are discarded from  $P_{t+1}$ .
- All solutions in the new population increment their corresponding elements in the pheromone matrix according to the inverse of their rank, i.e.  $\Delta \tau_{ij}^s = 1/(S_{rank})$ 

$$\tau_{ij}^s = \tau_{ij}^s + \Delta \tau_{ij}^s \quad (8)$$
- Create the offspring population  $Q_{t+1}$  with the application of crowded tournament selection based on Pheromone in each string, crossover and mutation operator on  $P_{t+1}$ .
- Test for convergence. If the algorithm has converged, then stop and report the results. Else  $t \rightarrow (t+1)$ ,  $P_t \rightarrow P_{t+1}$ ,  $Q_t \rightarrow Q_{t+1}$  and go back to step 4. Flowchart of CP-ACO Algorithm is shown in Appendix "A" at last page.

### IV. IMPLEMENTATION OF CP-ACO FOR SERVICE RESTORATION PROBLEM

In this work, before application of CP-ACO for solving service restoration problem, the original distribution network is mapped to a graph involving nodes and branches. Thus, the configuration of the original network is completely described by the status of the switches.

#### A. String Representation:

The entire switches in a particular distribution network are represented in terms of string of binary bits. The status of switches such as 'closed' and 'open' are shown '1' and '0' respectively. The length of the string (i.e. number of bits in string) is equal to number of switches in the system.

#### B. Generation of initial population:

Generally the initial population  $P_0$  is generated randomly. If the pre-fault network is well behaved and well balanced, then the final service restoration plan is expected to be near to the original configuration and hence a string according to original configuration is incorporated in initial population replacing any one string in randomly generated

population. The generation of the initial population is restricted to meet the following requirements.

- a. Root switches are always connected i.e. kept always equal to “1” in all the possible binary strings of the expected newly reconfigured network as the opening the root switch will isolate the entire bus system. Root switch is one nearest to the substation connecting the entire bus system.
- b. The faulted zone is always isolated by making the element in all strings, corresponding to switches around the faulted zone, “0”.

### C. Radiality Checking:

To check the radiality of the system, a breadth-first-traversal of the network starts from the root switch and travels downwards of the distribution network. The root switch from where the traversal starts is called the first level switch. If any switch under consideration is closed, the reachable zones connected to downstream side and hence, is marked “visited”. On the other hand, the unreachable switches connected at the downstream side are marked “unvisited”. After consideration of all first level switches, zones marked “visited” are entered in a list “L”. The switches connected to “visited” zone downstream side are called second level switches. The same procedure just mentioned for first level switches is repeated and list “L” is updated. The switches connected to zones recently admitted in list “L” are third level switches and the procedure is repeated again and again till there is no switch left in the next level. The earlier mentioned procedure is illustrated as follows for the network shown in Fig.2, in which switch  $S_1$  is root switch.

First level switch- $S_1$

Zones “visited” connected with first level switch- $Z_1$

Second level switches- $S_2, S_3$

Zones “visited” connected with second level switch- $Z_2, Z_4$

Third level switches- $S_4, S_5, S_7, S_8$

Zones “visited” connected with third level switch- $Z_3, Z_5, Z_7$

Fourth level switches- $S_6, S_9, S_{10}$

Zones “visited” connected with third level switch- $Z_6$

Fifth level switches-nil, all zones are “visited”

The presence of loop is detected if any of the zones is “visited” more than once during the traversal. The switch currently under considered is made ‘OFF’ to maintain the radiality. After the completion of network traversal all the “visited” zones are put list “EZ” called “existing zones”. The “existing zones” are actually energized zones.

### D. String evaluation:

After checking the radiality, all strings give a radial configuration and their corresponding existing zones are recorded through which existing buses and lines are found. With the knowledge of the existing buses all the objective functions are calculated for each string of population. AC load flow study is conducted to calculate system losses, bus voltage and line current violations.

### E. Initialization of ACO parameters:

- a. Number of ants
- b. Initial pheromone value  $\tau_i = \tau_{init}$  ( $\tau_{init} > 0$ )

- c. Pheromone parameter ( $\alpha$ )
- d. Heuristic parameter ( $\beta$ )
- e. unique heuristic exponent correction factors ( $\lambda$ )

### F. String Operation:

To generate the offspring population single point crossover method is used. GA operators i.e. selection, will be based on transition probability principle of ant colony algorithm given by equation (7). Moreover, the mutation operator is randomly applied in any string. After the offspring population is created, the radiality of all offspring population is checked and if any solution found non radial then is made radial according to the procedure mentioned in step C. Subsequently, with the help of crowded tournament selection operator based on pheromone matrix, the mating pool is created for next generation. This operator maintains the convergence as the solution from better front is selected and diversity as the solution having higher crowding distance within the same front is selected.

### G. Partial Restoration:

During the restoration process, if no such string in search space is generated which can restore entire out of service area without violating any constraint, the string, which can restore maximum portion of out of service area without violating any constraint, is selected and kept in better front.

### H. Front formation and ranking:

Following step 5 of section III, the combination of parent and offspring population having size  $2N$  is divided in various ranked nondominated fronts. If no better solution is generated in offspring, the current best solution in the parent becomes a winner and in this elitism is maintained to improve the convergence.

### I. Selection of new parent having $N$ strings:

$N$  strings for the parent population of the next generation from  $R_t$  (having  $2N$  strings) of the current generation are selected according to the procedure mentioned in step 6 of section III.

### J. Pheromone update:

All solutions in the new population increment their corresponding elements in the pheromone matrix according to the inverse of their rank as described in step 7 of section III.

### K. Convergence:

To check the convergence, at each generation, the candidate configurations in parent  $P_t$  and offspring  $Q_t$  are compared after they are made radial as mentioned in part C of this section. If both parent and child populations are same then convergence is achieved otherwise it is not.

### L. Selection of Final solution:

After convergence is achieved, the best solution is in first front of  $R_t$ . If the first front has the only one solution then obviously it is the optimum solution. But if the first front has more than one solution then final solution is chosen following ‘h’ stages where ‘h’ is the no of objectives. The solutions having minimum out of service

area will be considered string of better quality. If two or more strings have the same value of objective function of first priority, then objective of second priority is evaluated and the process is continued. In any stage only one solution is left then, it is considered the best solution.

**M. Steps of Algorithm for Service Restoration:**

- a. The information available to the ACO algorithm are (a) system data; (b) pre-fault configuration and (c) post fault configuration.
- b. Generate initial population  $P_0$  for ants following the procedure described in part B of this section.
- c. Check the radiality of the solutions in search space and modify them, if necessary, following the procedure described in part C of this section.
- d. Evaluate the strings in  $P_0$  as described in part D of this section and assign  $P_t = P_0$ .
- e. Initialize the parameters for ACO search as described in part E of this section.
- f. The ants are dispatched and solutions are constructed based on the level of pheromone on edges i.e. string of binary bits to be selected for crossover to generate offspring. The number of ants will be less than or equal to the number of strings generated in search space.
- g. Generate offspring population  $Q_0$  as described in part F of this section. In all strings of new offspring population, the faulted zone is isolated and the root switch is always made “closed” as described in part B of this section.
- h. Check the radiality of the strings in offspring population and modify them, if necessary as mentioned in part C of this section.
- i. Follow steps 4 to 8 of section III to obtain  $P_{t+1}$  and  $Q_{t+1}$
- j. In all solutions of  $Q_{t+1}$ , the faulted zone is isolated and root switch is always closed as described in step B of this section.
- k. Check the radiality of the strings in  $Q_{t+1}$  and modify them, if necessary as mentioned in part C of this section.
- l. Check for convergence as described in part K of this section. If the algorithm has converged, find the final solution according to part L, otherwise go to step XIII.
- m. Evaluate the strings in  $Q_{t+1}$  as described in part D of this section
- n. Update  $t \rightarrow (t+1)$ ,  $P_t \rightarrow P_{t+1}$ ,  $Q_t \rightarrow Q_{t+1}$  and go back to step IX.

**V. RESULTS AND DISCUSSION**

The effectiveness of the Ant Colony System algorithm for service restoration has been studied on three different distribution systems. The details of these systems are given in Table I.

Table 1: Details Of Different Test Systems

SL. No.	Description	No. of Buses	No. of Switches	Systems nominal voltage (KV)	No. of load points
1	System-1	13	10	11	12
2	System-2	10	14	13.8	19
3	System-3	33	37	12.66	31

The performance of proposed CP-ACO algorithm has also been compared with Non-dominated Sorting of Genetic Algorithm NSGA-II developed by Deb [30] and conventional GA developed by Laun *et al* [13]

Here the results corresponding to 10 bus, 14 switches system (system-2) are only illustrated. Fig. 1 shows the schematic diagram of the 10-bus,14-switch system. In this system, it has been assumed that the fault has taken place at point A (also indicated in Fig.1) and due to this fault, the switch  $S_4$  trips for isolating the fault. As a result, the area shown inside the closed curve is left without electric power. The supply to this “out-of-service” area can be restored either by closing switch  $S_{14}$  (let it be called option A) or by closing switch  $S_{12}$  (let it be called option B). Now, switch  $S_{12}$  is an automatic, remote controlled switch with a typical operating time of 50 seconds whereas, switch  $S_{14}$  is a manually controlled switch with operating time typically in the range of 1200-1500 seconds. It is to be noted that the operating time of a manually controlled switch depends on its distance from the nearest manned substation (from which an operator has to travel to operate the switch). Now, by both these options, the entire “out-of-service” area can be supplied. Therefore, from the considerations of the objective function kept at first

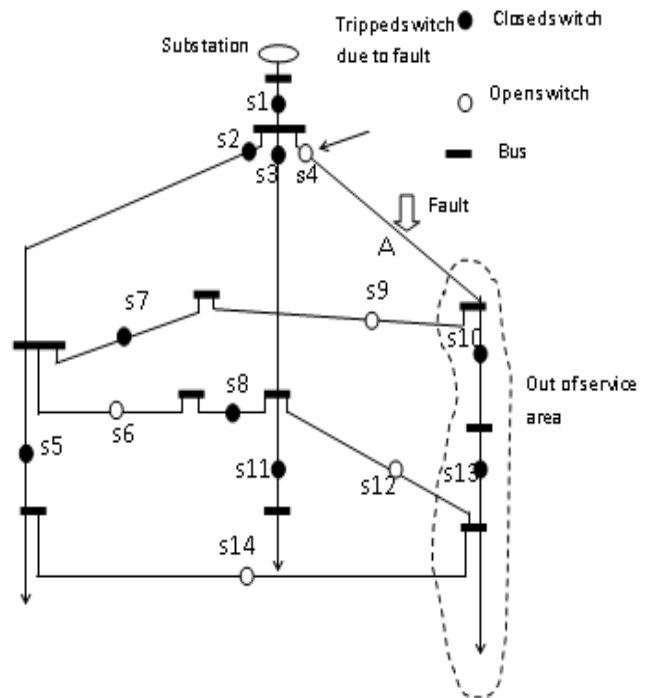


Figure 1. 10 bus, 14-switch system

Preference, both these options are equally preferable. However, as option B takes considerably less time as compared to option A to accomplish the service restoration task, this option is chosen. Similar kind of studies for different single fault in all three systems under consideration is shown in Table II.

Table 2: Various Single Fault Locations

System	System-1	System-2	System-3
<b>Fault location</b>	<b>z4 (between bus 4 and 8)</b>	<b>z6 (between bus 1 and 4)</b>	<b>z4 (between bus 3 and 4)</b>
Priority customer	z6	z3	z21
Switch tripped due to fault	3	4	9
Remotely controlled switches	1, 4, 7	1,2,3,7,12	2,3,6,8,11,24,34

Various GA-ACO algorithm parameters are shown in Table III.

Table 3: Parameters Setting In Test Cases

Parameters	Value
Size of Population	10
Number of Ants	10
Maximum no of iterations	100
Initial Pheromone on strings	0.1
Cross over rate (Single Point)	0.8
Mutation Rate per gene(bit)	0.05

In the result tables, the entries corresponding to the “out-of-service” area has been given in terms of the total amount of load (in KW) left unsupplied. For example, from Table IV, it can be concluded that 600 KW of total load is always left unsupplied in system-1, irrespective of whichever solution methodology is used. Actually, in system-1, the load in the faulted zone is 600 KW and as this zone is isolated following a fault, this load cannot be restored by any technique. Similarly, the faulted zones in system-2 and system-3 contain 100 KW and 120 KW of load respectively and as a result, these loads can also not be restored by any of the methods. Moreover due to generation of lot of infeasible solution on the basis of probability in conventional GA, run time required for the algorithm is very high in comparison to proposed CP-ACO technique. NSGA-II developed by Deb [30] also require more time than CP-ACO. Conventional GA requires more manual switch operations than NSGA-II and CP-ACO. All the three methods are able to restore Priority customers. Based on results in Table IV, CP-ACO based technique is found to be the best technique among three.

Table 4: Single Fault Full Service Restoration

System		System-1	System-2	System-3
Out-of-service Area (KW)	CPACO	600	100	120
	NSGA-II	600	100	120
	GA	600	100	120
No. of manual Switch operation	CPACO	2	1	1
	NSGA-II	2	1	1
	GA	3	2	2
No. of Automatic Switch Operation	CPACO	2	1	1
	NSGA-II	2	1	1
	GA	1	0	0
Losses (KW)	CPACO	104.50	582.40	210.00
	NSGA-II	104.50	582.40	210.00
	GA	106.86	579.0	216.0
Run-time of Algorithm (seconds)	CPACO	14.113	17.534	41.313
	NSGA-II	22.538	30.121	75.812
	GA	43.807	64.910	195.311
Status of Priority Customers	CPACO	Yes	Yes	Yes
	NSGA-II	Yes	Yes	Yes
	GA	Yes	Yes	Yes

When the active and reactive loading at all buses of the three distribution systems under study are uniformly increased from the ‘base loading conditions’ then in fault studies the power supply could only be restored partially and restoration plan is called ‘partial service restoration’. The percentage increase of the loading which have been considered in this case are as follows: System-1-128%, System-2-130% and System-3-125%. In these cases the same single fault locations are considered as mentioned in table II. From the table V, it is observed that CP-ACO and NSGA-II has same out of service area but GA proposes more out of service area for system-2. Moreover GA requires more manual switch operation than CP-ACO and NSGA-II to perform the task. Run time of algorithm is lowest in case of CP-ACO. GA proposes less line losses for system -2, while more line losses for system-1 and 3. GA based method is not able to restore service in priority customer zones for System-1 and Sytem-3.

Table 5: Single Fault Partial Service Restoration

System		System-1	System-2	System-3
Out-of-service Area (KW)	CPACO	1344	260	240
	NSGA-II	1344	260	240
	GA	1344	650	240
No. of manual Switch operation	CPACO	3	3	3
	NSGA-II	3	3	3
	GA	4	2	3
No. of Automatic Switch Operation	CPACO	2	1	2
	NSGA-II	2	1	2
	GA	0	0	2
Losses(KW)	CPACO	99.834	578.37	191.4
	NSGA-II	99.834	578.37	191.4
	GA	98.797	533.14	199.3
Run-time of Algorithm (seconds)	CPACO	13.193	15.273	39.117
	NSGA-II	21.976	29.789	75.291
	GA	43.782	65.117	195.64
Status of Priority Customers	CPACO	Yes	Yes	Yes
	NSGA-II	Yes	Yes	Yes
	GA	No	Yes	No

## VI. CONCLUSION

In this paper, CP-ACO based technique is developed and analyzed for solving the service restoration problem in the electric power distribution system. In this study, various practical issues of distribution system operation, such as presence of important key customers like hospitals, industries are considered. Moreover manually controlled switches and remotely controlled switches are considered separately as objective function which helps in applying restoration plan practically in short time as the operating time of manually controlled switches are significantly high in order of 1200-1500 seconds in comparison to remotely controlled switches having operating time of 50-60 seconds. The advantage of the proposed CP-ACO based technique is that it does not require weighting factors as needed in conventional optimization techniques. Moreover the proposed technique overcomes the demerits of GA and ACO both. Demerit of GA to produce infeasible solution is controlled by positive feedback mechanism based on pheromone of ACO and demerit of ACO to take large convergence time is controlled by controlling the no of ants and size of search space generated by GA. Based on larger number of simulation studies, it has been found that the CP

ACO based technique performs far better than conventional GA in all respects and significantly better than NSGA-II in respect of run time of algorithm. Number of iterations required to get best solution is also very less in comparison to NSGA-II and GA. It is therefore CP-ACO based technique is most suitable for real time implementation both in terms of accuracy and speed.

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