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AACO Technique For Solving Multiobjectives in Electrical Distribution System

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ABSTRACT

The goal of electrical distribution networks is to restore electricity with as little resistance as possible over the network's architecture. This article went through many revisions before being accepted on February 22, 2019. The most likely strategy for doing this is to restructure artificial ant colonies. Quickly restoring full service is essential. Once the malfunctioning part is removed, the system may function normally again. Power outages are a certainty if something occurs. To provide continuous power, these loads must be supplied by nearby healthy feeders via reconfiguration without affecting routine, load balancing, or other needs. There is a 30%-40% Holmic loss that is taken into account by the manner of distribution. A power flow study should be performed to determine the bus voltages, branch currents, and power losses in the system before any changes are made to reduce these losses (i.e., real or Holmic or copper loss and reactive power loss). The suggested research employs a direct load flow analysis to get to the bottom of problems. The IEEE 33 bus and IEEE 69 bus testing systems help minimize harmonic losses, while the IEEE four feeder testing system facilitates power restoration in the event of a blackout..

1. INTRODUCTION

Information on the many energy sources used, transmission and distribution losses, and more are all included.

Power System

The electrical infrastructure consists of three main parts. This includes everything that is manufactured, distributed, and communicated. All necessary components, such as power and distribution transformers, current and potential transformers, line and bus bar reactors, neutral wires, insulation, lightning arresters, circuit breakers, isolators, relays, and so on, are included.

Generation

Both conventional (nonrenewable) and renewable (renewable) resources may be used to produce electricity in this context. Renewable resources such as the sun, wind, and other natural phenomena are the sources of this kind of energy. The sun, wind, and tides, as well as the Earth's own internal heat and chemistry, are all examples of renewable energy sources. These materials may be recycled several times. Using nonrenewable resources to generate energy wastes limited, irreplaceable resources. It's safe to say that heat, water, atoms, and oil are among the most pervasive substances in the universe. The 11kV of output from an Indian power plant is known to vary from week to week. As there is just one power plant, the frequency of our electricity (50HZ) is reliable (kVA, MVA.Etc.). A 5% swing in voltage and a 2% swing in frequency are both possible.

2. LITERATURE REVIEW

The formula for reducing power loss was discovered by Caviler& Grainger [1], however in this study we apply the "branch interchange" technique to arrive at the same result in a much shorter amount of time. This article by D. Shi Mohammadi and H.W. Hong [2] discusses strategies for decreasing resistive loss and, by extension, processing time. To enhance precision and speed up computations, M.E.Barnful [3] use two separate load flows. By instituting measures to foresee power flow, we were able to halve our power losses while maintaining the same load. To lessen the effort and time needed to find anything, Taylor and Lubkeman [4] developed a rule-based method. J.Z.Zhu [5] presented the findings of his research on the use of a genetic algorithm with certain tweaks to the reconfiguration of distribution networks. Power loss may be estimated using the load flow approach of a radiation distribution network, with the ultimate goal being to reduce losses to an absolute minimum. Jorge Mendoza et al. [6] present a formal and rigorous technique based on an evolutionary algorithm to address such enormous optimum reconfiguration problems. After this rewiring is complete, there should be very little power loss in the system. Reconfiguration employing ant colony optimization and heuristic search may help with overcrowding, service restoration, and imbalanced load. F.S. wanted to minimize EDS's energy use throughout the reconfiguration process. A metaheuristic strategy was presented by Pereira, K. Vittori, et al. [9]. Two ACO methods, the traveling salesman method (TSM) and radial system reconfiguration (RSR), are used to enhance a conventional five-bus sample system (CRS). The author concludes that a radial system reconfiguration technique based on ant colony optimization is the best approach.

3. THEORETICAL ANALYSIS

The design and needs of radial and ring main electrical power distribution systems are covered, along with load flow studies/power flow analysis, component modeling, and load flow methodologies.

4. ELECTRICAL POWER DISTRIBUTION SYSTEM

A power distribution system is characterized by its low voltage and the diverse needs of its consumers (domestic, industrial, agricultural, etc.). (That is, single phase voltage is 230 volts and three phase voltage is 440 volts). In order to provide power to the customer, distribution networks require feeders, distributors, and consumers.To replenish the supply lines. The most crucial ones are highlighted here:

These are some common examples of parts found in distribution networks:

- An electrical distribution substation is located here.
- Probably the single most crucial part of one's diet,
- Electronic Power Conversion and Distribution Transformers
- Professions Engaged in Sales,
- Pipes for transporting water,
- Loads

Energy is transmitted from the substation to the consumers over an overhead power line known as the main feeder. The transformer maintains a consistent frequency and primary distribution rate for the system voltage (rail poles are preferable). Insulated pins are used to secure strands of aluminum conductors to the pole's legs. Main distribution using subterranean cables is frequently the most efficient option in densely populated regions. Figure 6 depicts one such example of a centralized distribution system.

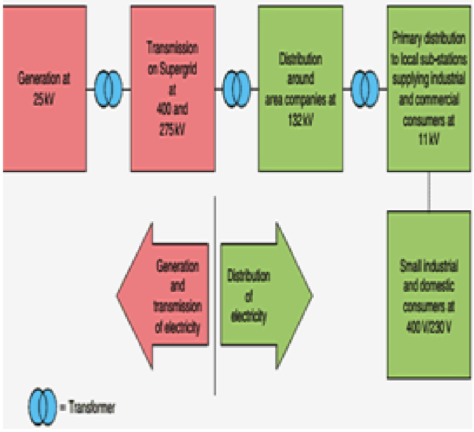

Figure1: Primary Distribution System

In distribution systems, three-pole transformers are a common transformer configuration. The distributors are wired to the secondary transformer. These days, the majority of the population has some kind of connection to the mains electricity supply. The majority of distributors concentrate their service hubs in a small number of key nodes. Those sellers may also be categorized as distributors or sub-distributors. Power distribution panels are separated from sub-distribution panels using electrical tape, and secondary distribution transformers are hooked into the main panels. The client is responsible for approving the connection between the service mains and the sub- or distributors and being aware of its exact position. In this component of the electric power distribution system, it is crucial to keep in mind the key differences between feeders and distributors. While the feeder is in charge of carrying electricity directly from one point to another, the distributor is in charge of conveying electrical loads from the generator to the consumer. Since there is no sag to restrict the flow of current, it may flow in any of many directions. Feeder dimensions are determined by power demand. Distributors were made with voltage drop minimization in mind. As distributors are redirected to serve new clients, there will be differences in the cable current.

5. LOAD FLOW STUDIES/POWER FLOW ANALYSIS

Main Objectives

- The prospective results of modifying the physical structure of the electricity grid are examined in a design and planning research (such as adding or removing devices).
- Verifying the rates and amounts of force supplied to equipment is crucial for ensuring its safety.
- This strategy is based on the idea of steady-state stability analysis.
- To see how well a conventional configuration holds up under extreme conditions, it may be used on that setup.
- Network load distribution analysis is required to determine the individual device stability margins.
- Load flows may be used to measure a system's efficiency.
- Research into transient stability and unusual fault circumstances is improved by doing load flow testing.
- The optimal placement of Q-compensating equipment and the ratings for the compensators are both dependent on a thorough examination of the load flow.

Assumptions to be taken

- A generator may either be a continuous infusion of complex power or a reliable supply of actual power. The voltage and current of the system are controlled by the PV bus, also known as the generator bus.
- Real and reactive powers (P and Q) are used to characterize the load, which may be supplied or drawn from the system at a constant rate.
- A transform as shown by an impedance series (i.e., Series reactance, resistance is assumed to zero Ohms).
- Since transformers contain two parallel branches that incur losses due to copper and magnetizing resistance, the shunt branches are often disregarded.
- Nominal-T or Nominal-model is often used while discussing transmission lines.
- We can do a load flow analysis now that the system has stabilized.
- Harmonics are absolutely missing here.

- You should keep in mind that we're assuming a universally constant frequency.
- High voltage direct current (HVDC) cables are prohibited from bearing any weight.The steady-state activities are described by the inputs of line and bus data (as seen in Figure 9).

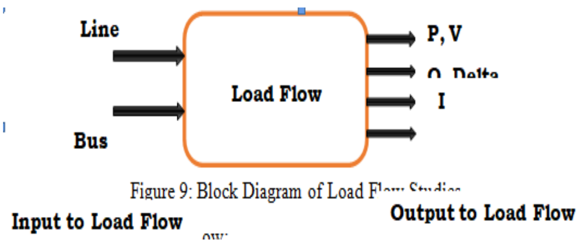

Figure 2: Block Diagram of Load Flow Studies

Things we must know about load flow:

1. To determine V and at each node, a load flow analysis must first solve a set of nonlinear algebraic power equations.
2. The ideal load gauge would be simple to use, quick, and accurate.
3. Each node's data on line losses, phase angle, injected power, and voltage are recorded.
4. Load flow analysis often employs the following technique
5. Running a virtual electrical circuit on a computer is one technique to demonstrate its inner workings
6. It would need nothing more than a perfect set of formulae to divide up the labor.
7. Modern computational methods, however, could provide the crucial insights.

6. PROBLEM STATEMENT

Overloading may occur in an electrical distribution network if the load is distributed unevenly. Since the voltage is reduced, the feeder is being stressed beyond its thermal limits (i.e., open circuited). When it comes to dependability, however, service restoration is usually only given thought during times of crisis. This may improve the reliability of power delivery to loads, but it won't quite reach the target of 100%. When the power losses from resistance and inductance are added together, the total power loss (perceived power loss) is obtained. The system needs reactive power so that the voltage doesn't fluctuate. As the quantity of actual power loss increased, the system's efficiency deteriorated. Damage to the system as a whole resulted from an increase in reactive power loss brought on by a dead short circuit caused by insulation breakdown on the conductors as the voltage in the system rose.

7. PROBLEM INVESTIGATION

Includes background information, a mathematical model for restoring service and balancing load, and a strategy for limiting Holm's financial impact.

8. PROBLEM FORMULATION

Service Restoration

Seek for the faulty feeder and shut off the electricity to that circuit. Determine which places are without connectivity as a result of the issue. Modify the system using long-baseline interpolation (LBI) techniques (1).

$$LBI = \frac{1}{n}\sqrt{\sum (Y - Y_i)^2}$$

Where: n= no. of primary feeders; Y=average of the normalized loadings Yi

$$Y_i = \frac{i^{th} - \text{Feeder Actual Loading}}{i^{th} - \text{Feeder Base Loading}}\text{; i=1, 2, 3....n}$$

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Subjected to following constraints:

$$Si \leq Sri$$

$$Pi \leq Pry$$

$$Qi \leq QRi$$

Where: I=1, 2, 3….n; n= no. of primary feeders Si=MVA loading on feeder – I ; Sir=Rated MVA on feeder - I Pi=MW loading on feeder – I; Pry=Rated MW loading on feeder - I I=MVAR loading on feeder – I ; Ri=Rated MVAR on feeder – I

Key requirements, such as load balance, ritual, and acceptability, must be met before any modifications are made. Locate the minimal LBI-scoring combination that meets all requirements.

Power Flow Analysis - Direct Load Flow Method (DLFM)

This method may be used to examine power flows in an overburdened, poorly meshed distribution network. This process may be broken down into three distinct phases. By adding a current of the same wattage, b. The BIBC matrix was conceived. The Matrix is Formed via BCBV Interactions

Equivalent Current Injection

When electricity is included, it becomes entirely mechanical. The solution is iterated n times, at which point the bus is supplied with the apparent power of Si and the correct amount of current is injected.

$$S_i = P_i + jQ_i$$

$$I_i^n = \left(I_i^{Real} V_i^n\right) + j\left(I_i^{Img} V_i^n\right) = \left(\frac{S_i}{V_i^n}\right)^*$$

Where: I=1, 2, 3, 4… N

S_i is the apparent power at i^{th} bus; P_i is the real power at i^{th} bus.

Q_i is the reactive power at i^{th} bus; V_i^n is the bus voltage at the n^{th} iteration for i^{th} bus.

I_i^n is the equivalent current injection at the n^{th} iteration for i^{th} bus.

I_i^{Real} & I_i^n are the real and imaginary parts of the equivalent current injection at the n^{th} iteration for i^{th} bus.

9. PROPOSED METHODOLOGY

An overview, technique explanation, and workflow diagram for the artificial ant colony optimization method are provided here.

10. ARTIFICIAL ANT COLONY OPTIMIZATION

This method may be used to nonlinear issues in any discipline. Ant colony optimization seeks to deliver the best possible outcome by mimicking the behavior of ants as they search for a minimum or maximum value.Pheromones are chemical molecules that foraging ants leave behind to signal the rest of the colony that food has been found. If ants detect a pheromone trail, they will follow it. Ants use a system of pheromone trails to navigate to food sources. Without a designated leader, a group of ants will simply continue to follow the pheromone trail. They're all moving in lockstep, like a military formation. Why? Since ants usually choose the quickest route (i.e., higher pheromone intensity).Figure 16 depicts a healthy ant colony, whereas Figure 17 shows one that is in difficulty. Pheromone concentration rises more sharply with shorter distance, as seen by a larger line.

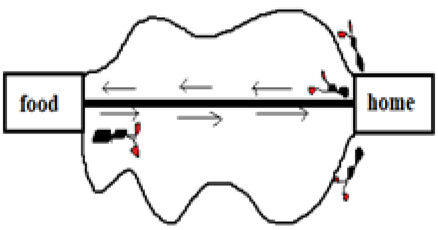

Figure3: Behavior of Ants in the Wild

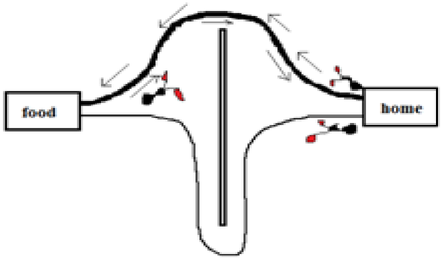

Figure 4: Natural Behavior of Ant with Obstacle

An EDS's n switches may be configured in almost infinite permutations (PTR). Foreseeing whether or not an ant will choose a certain route may be done with the help of Probability of a Path Selection (PTR). If a network uses ten switches, for instance, there are 1024 different configurations. With PTR's assistance, this figure may drop to 10, and the final solution would be more robust. The following formula may be used to determinePTR:(22)

$$P_{i,j}^{k}(t) = \frac{[\tau_{i,j}(t)]^{\alpha}[\eta_{i,j}(t)]^{\beta}}{\sum_{l}[\tau_{i,j}]^{\alpha}[\eta_{i,j}]^{\beta}}$$

Where'd, q $\in N_i^k$.
N_i^k is a list in the memory of ant that records the cities which will be visited to avoid stagnations.

I, j is the travel path of ants.
$\eta_{i,j}$=pheromone trail deposited between the nodes i, j.
$\eta_{i,j}$==represents the heuristic information=$\frac{1}{d_{i,j}}$.
$d_{i,j}$= distance between city i and j.

$\propto, \beta$ =Pheromone trail utility and the accuracy of the heuristic guiding function may be fine-tuned by adjusting the parameters (, =).

The local pheromone is recalculated after each excursion using the following formula: (23). Multiple pheromones present within the same time interval (. (imp) (t)) add up to the overall strength of the pheromone.$(\rho.\tau_{i,j}(t))$ and new pheromone intensity$(\Delta\tau_{i,j})$.

$$\tau_{i,j}(t+1) = (\rho.\tau_{i,j}(t) + (\Delta\tau_{i,j})(23)$$

Where:$\Delta\tau_{i,j} = \sum_{i=1}^{l} \Delta\tau_{i,j}^{k}$
$\Delta\tau_{i,j}^{k} = \frac{Q}{L_k}$, if ant k travels on edge (imp) otherwise it is zero.
Where: t =iteration counter ; k= 1, 2….l ants.
Q=constant; L_k=length of tour.

11. ALGORITHM

1. Test methods for buses such as the IEEE 3-Feeder, 4-feeder, IEEE 33, and IEEE 69 should be thought about.
2. Do not continue if the feeder is full. If such is the case, then go through with the new setup and the verification procedure. Otherwise, check for technical problems with the system.

Overloaded condition

Except for if the feeder gets overloaded again after the configuration change, the LBI is calculated, the least LBI is provided, and the procedure is complete.

Fault condition:

1. Find the malfunctioning part and take it out of service to get things back to normal. You'll have free reign to rearrange things afterwards.
2. You should reset everything to normal if doing so won't interfere with any rituals.
3. It's over; you should go.
4. Assuming there are no snags, we can make the required number of ants, turn on the system, and update both the local and global pheromones (such as an overload or a flaw).
5. Convergence rates may be increased by computing the probability transition rule, potentially reducing the likelihood of catastrophic events. To keep track of everything that might happen, make a list.
6. Adjust the settings to permit the following permutations, and then double-check that the ritual works properly in each of them.
7. If the requisite ritualism is met, then do a power flow analysis using the direct load flow method to determine the voltage, current, and real and reactive power losses for each arrangement.
8. Select the ideal reactive power loss solution by entering the switch states, the voltages and currents of interest, and the actual and reactive power losses.
9. Terminate.
10. This process is shown in flowchart form in Figure 18.
11. IEEE 33 bus and 69 bus systems, as well as IEEE three feeder and IEEE four feeder systems, are used to develop and test the proposed method for Holmic loss reduction, load balancing, and service restoration. The graphic specifics are in chapter 6.

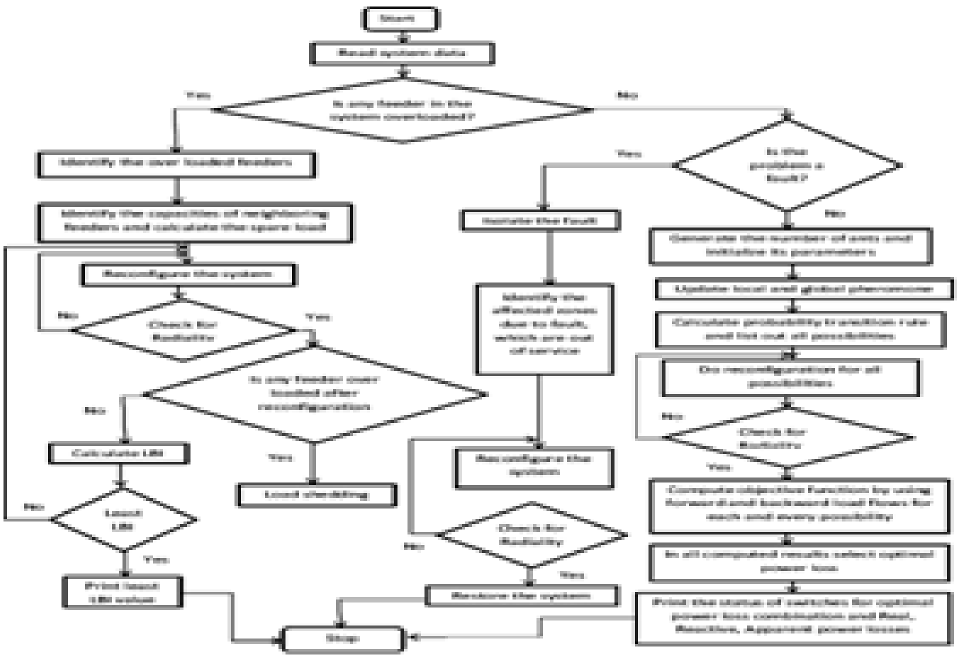

Figure 5: Flow Chart for Artificial Ant Colony Optimization Method

IEEE Three feeder load balancing

The system won't be adjusted until the underutilized feeder, the neighboring feeder's capacities, and the overloaded feeder have all been recognized. After the rewiring is done, we'll measure the load to determine whether any feeds are still overloaded. If the LBI is kept low enough, the load is distributed uniformly over the structure. With a load balancing index of 0, all tasks are split evenly among the available workers.

The obtained load data for testing the IEEE three fee detest system is shown in Table 1. (Figure 19). The dotted lines represent the switches that divide the network into 15 distinct sections, while the solid lines indicate the connections between the remaining 3 nodes (i.e., dotted lines). The forks are categorized from A to P according to their uses. The maximum amount of electricity that may be distributed by a single feeder is 15MVA. After a rearrangement, only three of the original six tie switches in the network architecture of the system are still functional (C, K, and P). Load balance index is a metric used to evaluate the efficiency of load distribution (LBI). The IEEE test system was delivering an excessive quantity of data across its three channels before the system was reconfigured.

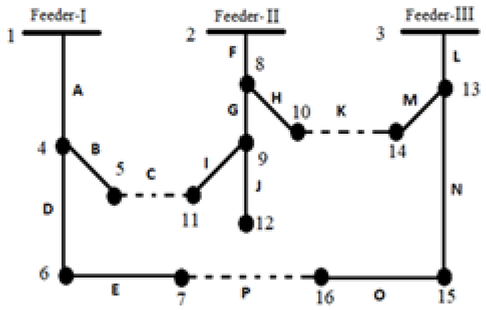

Figure6: IEEE Three Feeder Test System

Table 1: IEEE Three Feeder Load Data

From bus –to bus	R(ohm)	X(ohm)	End bus load (MW)	End bus load (MVAR)
	Feeder-I		Feeder-II	Feeder-III
1-4	0.075	0.10	2.0	1.6
4-5	0.08	0.11	3.0	1.5
4-6	0.09	0.18	2.0	0.8
6-7	0.04	0.04	1.5	1.2
2-8	0.11	0.11	4.0	2.7
8-10	0.08	0.11	5.0	3.0
8-9	0.11	0.11	1.0	0.9
9-11	0.11	0.11	0.6	0.1
9-12	0.08	0.11	4.5	2.0
3-13	0.11	0.11	1.0	0.9
13-14	0.09	0.12	1.0	0.7
13-15	0.08	0.11	1.0	0.9
15-16	0.04	0.04	2.1	1.0
7-16	0.04	0.04		
5-11	0.04	0.04		
10-14	0.09	0.11		

Before reconfiguration: feeder-I loading is 9.912618 MVA, feeder-II loading is 17.426990 MVA and feeder-III loading is 6.185466 MVA. Feeder-II is overloaded by 2.426990 MVA, Tie switches are C, K and P.After reconfiguration: feeder-I loading is 12.801562 MVA, feeder-II loading is 11.027692 MVA and feeder-III loading is 12.030793 MVA. Among all possible combinations, all feeders are in balanced condition, least LBI value 0.027953 achieved by Optimal Tie switches H, I and O. here get some possible combinations for reconfiguration those are shown in below table 2.among those, H, I, O tie switches combination solves overload problem as well as it gives least LBI value (i.e. LBI=0.027953 load on system more balanced compared to all possible combinations LBI values shown in below table 2 highlighted in bold letters) this is nothing but optimal value of LBI obtained after reconfiguration. Before and after reconfiguration loading on three feeders are shown in table 3.Table 2: After Reconfiguration Possible Tie Switches Combinations and its LBI Values

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S.no	Tie switches	LBI
1	N,B,H	0.106586
2	N,I,H	0.090273
3	D,G,K	0.041149
4	C,P,H	0.034929
5	H,I,O	0.027953

IEEE Four Feeder Service Restoration

Figure 5 shows the IEEE four feeder test system that was used to evaluate the proposed AACO method. All 16 sectionalized switches are closed (such as switches 2, 3, 4, etc.) and all 15 tie switches are open (for example, switches 6, 7, and so on). A 10,000 kVA circuit breaker is used for each of the four feeds into the system (1, 11, 21, and 31). The zone burdens are shown in Table 1.

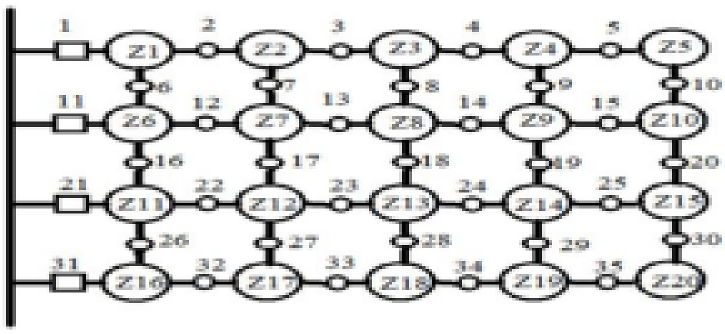

Figure7: Single Line Diagram of IEEE Four Feeder Test System

Table3: IEEE Four Feeder Test System

Zone number	Zone load (kVA)
1	1600
2	700
3	1800
4	500
5	1900
6	500
7	1500
8	1000
9	500
10	800
11	3000
12	3500
13	700
14	1000
15	600
16	1500
17	2000
18	1800
19	1500
20	500

Each feeder has a maximum load of 10,000 kVA, however the actual loads on A, B, C, and Dare 6,500, 4,300, 8,800, and 7,300 kVA, respectively. Suppose four feeder systems have had a series of random failures to illustrate the suggested technique (i.e.,feeder A, B, C, and D at positions Z1, Z8, Z14, and Z17 respectively).

Case-1: The Switch 1 A feeder has failed. An equivalent of a "circuit breaker," in other words.
By cutting off electricity at Switch-1, the faulty circuit may be safely removed from the system.
To prevent power outages, every electrical device must be hardwired into an outlet.Important shipments are rerouted to prevent potential holdups.

Before Reconfiguration:
As a result of Feeder A's inactivity, 4300 kVA are being drawn from the grid by Feeder B.
There is a differential of 8800 kVA from C to D, and a difference of 7300 kVA from D to E.

After Reconfiguration:
The indicators at 6 and 20 o'clock on the dial are both turned off (or "zero").
Switch 15 opens to disconnect feeder A from the mains (a tie switch).
Feeder B has a capacity of 10,000 kVA, Feeder C of 9,600 kVA, and Feeder D of 7,300 kVA.

Case-2: Fault on feeder B at position Z8
Because of fault, faulted section is separated by opening switches 13 and
14. Discarded load on feeder B is 2300 kVA.

Before Reconfiguration:
Load on Feeder A is 6500 kVA, whereas that on Feeder B is just 2000 kVA.
Between C and D, there is a difference of 8800 kVA, and between D and E, there is a difference of 7300 kVA.
After Reconfiguration:
Toggle number nine is in the "closed" position (sectionalized switch).
It is the responsibility of Substation A to handle 7800 kVA, Substation C to handle 8800 kVA, and Substation B to handle 2000 kVA.
A maximum of 7,300 amperes may be fed into Feeder D.

Case-3: Inspection revealed that Z13 on feeder C was broken.
Power may be cut to the faulty devices by toggling switches 23 and 24.
24. It has come to light that 2300 kVA of capacity are being wasted on Feeder C.

Before Reconfiguration:
Feeder A can provide up to 6500 kVA, whereas Feeder B can send up to 4300 kVA.
As an example, the maximum capacity of feeder D is 7300 kVA, whereas that of feeder C is 6500 kVA.

After Reconfiguration:
Although feeder D's load is much higher than the others, at 6800 kVA, it is still significantly lower than that of feeder A (6500 kVA). There are 3 toggles for tying (19, 30, and 35). The conditional switch setting of 35 is in effect (i.e., a sectionalizing switch).

Case-4: We traced the problem back to the Z14 feeder C.
Switches 24 and 26 may be used to isolate a problematic section of the system from the rest of the computer while everything else continues to operate normally.
25. About 1600 kVA of load has been abandoned on feeder C.
Before Reconfiguration:
Feeder A is at 6500 kVA, while feeder B is at 4300 kVA.
Compared to Feeder D's 7300 kVA capacity, Feeder C can handle 7200 kVA.
.
After Reconfiguration:
Switch 20 is closed, resulting in a 6500 kVA demand on feeder A, a 4900 kVA burden on feeder B, a 7200 kVA load on feeder C, and a 7300 kVA load on feeder D. (a sectionalized switch).

Case-5:A Z17 pole has been damaged in distributor D.
Switches 32 and are opened to cut power to the malfunctioning part of the circuit.
33. About 5,800 kW of power is being lost due to inefficiency in Feeder B.

Before Reconfiguration:
Feeder A has a capacity of up to 6500 kVA, while Feeder B can take up to 4300 kVA.
Feeder C (8800 kVA) and Feeder D (2400 kVA) are responsible for distribution (1500 kVA).

After Reconfiguration:
The switches are all closed in positions 10, 19, and 29. Switches 15 and 24 are open, and the feeders are sectioned off with 7800 kVA on Feeder A, 2000 kVA on Feeder B, 8800 kVA on Feeder C, and 7300 kVA on Feeder D. (tie switches). There will very certainly be a slew of errant bugs, and your setup decisions will vary based on the specifics of those issues. The only method that can provide a steady flow of electricity at all times is the best reconfiguration of the IEEE four feeder system (i.e., system restored back and make dependable supply in fault condition also) (table 5).

12. IEEE 33 BUS TEST SYSTEM

The IEEE 33 bus testing system was used to put into action the suggested strategy. The nominal voltage of the test system is 12.66 kilovolts, the base MVA is 100, the total real and reactive loads are 3715 kilowatts and 2300 kilovolt-ampere-seconds, respectively, and there are a total of five tie switches. The S1–S32 sectioning switches and the T1–T32 tie switches in the network started off with their factory settings (S33 through S37). There are total power losses of 243.6 kVA, consisting of 202.6771 kW of real power loss, 135.1410 car of reactive power loss, and 243.6 kVA of perceived power loss. Since this is the optimal arrangement obtained by the proposed method, switches S29, S33, S34, S35, and S37 are all tie switches (represented by dashed lines), while the other switches are all sectionalizing switches (see Figure 6). With this set-up, we lose 109.6065 kW, 78.038 car, and 134.5494 kVA of power. When everything is considered, it's possible that the relative loss may be cut by 45.9206%.

Figure 8 .33 Bus test system after reconfiguration

Table4: Line Data for IEEE 33 Bus Test System

From bus	To bus	R (ohm)	X (ohm)
1	2	0.0922	0.047
2	3	0.493	0.2511
3	4	0.366	0.1864
4	5	0.3811	0.1941
5	6	0.819	0.707
6	7	0.1872	0.6188
7	8	0.7114	0.2351
8	9	1.03	0.74
9	10	1.044	0.74
10	11	0.1966	0.065
11	12	0.3744	0.1238
12	13	1.468	1.155
13	14	0.5416	0.7129
14	15	0.591	0.526
15	16	0.7463	0.545
16	17	1.289	1.721
17	18	0.732	0.574
2	19	0.164	0.1565
19	20	1.5042	1.3554
20	21	0.4095	0.4784
21	22	0.7089	0.9373
3	23	0.4512	0.3083
23	24	0.898	0.7091
24	25	0.896	0.7011
6	26	0.203	0.1034
26	27	0.2842	0.1447
27	28	1.059	0.9337
28	29	0.8042	0.7006
29	30	0.5075	0.2585
30	31	0.9744	0.963
31	32	0.3105	0.3619
32	33	0.341	0.5302
25	29	0.5	0.5
8	21	2	2
12	22	2	2
9	15	2	2
18	33	0.5	0.5

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Table 5: Bus Data for IEEE 33 Bus Test System

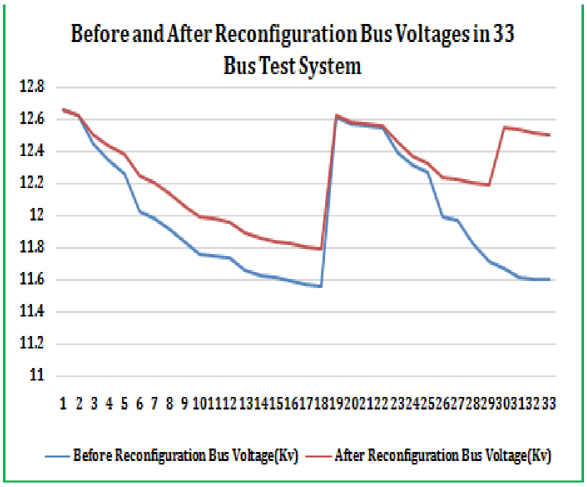
Bus_I	Pd	Qd	Bs	Base kV	Vmax	Vmin
1	0	0	0	12.66	1.05	0.95
2	100	60	0	12.66	1.05	0.95
3	90	40	0	12.66	1.05	0.95
4	120	80	0	12.66	1.05	0.95
5	60	30	0	12.66	1.05	0.95
6	60	20	0	12.66	1.05	0.95
7	200	100	0	12.66	1.05	0.95
8	200	100	0	12.66	1.05	0.95
9	60	20	0	12.66	1.05	0.95
10	60	20	0	12.66	1.05	0.95
11	45	30	0	12.66	1.05	0.95
12	60	35	0	12.66	1.05	0.95
13	60	35	0	12.66	1.05	0.95
14	120	80	0	12.66	1.05	0.95
15	60	10	0	12.66	1.05	0.95
16	60	20	0	12.66	1.05	0.95
17	60	20	0	12.66	1.05	0.95
18	90	40	0	12.66	1.05	0.95
19	90	40	0	12.66	1.05	0.95
20	90	40	0	12.66	1.05	0.95
21	90	40	0	12.66	1.05	0.95
22	90	40	0	12.66	1.05	0.95
23	90	50	0	12.66	1.05	0.95
24	420	200	0	12.66	1.05	0.95
25	420	200	0	12.66	1.05	0.95
26	60	25	0	12.66	1.05	0.95
27	60	25	0	12.66	1.05	0.95
28	60	20	0	12.66	1.05	0.95
29	120	70	0	12.66	1.05	0.95
30	200	600	0	12.66	1.05	0.95
31	150	70	0	12.66	1.05	0.95
32	210	100	0	12.66	1.05	0.95
33	60	40	0	12.66	1.05	0.95

The total installed Active power is **3715 kW** and Reactive power is **2300 kVAR**, Sybase=100 MVA, Vbase=12.66 kV.

Table 6: Improved Voltage Magnitude of IEEE 33 Bus Test System

Bus No.	Before Reconfiguration Bus Voltage(kV)	After Reconfiguration Bus Voltage(kV)
1	12.66	12.66
2	12.6224	12.631
3	12.444	12.4983
4	12.3493	12.4374
5	12.2556	12.3788
6	12.0227	12.2417
7	11.9785	12.1984
8	11.9172	12.1382
9	11.8379	12.0604
10	11.7642	11.9882
11	11.7533	11.9775
12	11.7344	11.9589
13	11.657	11.883
14	11.6283	11.8548
15	11.6104	11.8373
16	11.5931	11.8203
17	11.5674	11.7951
18	11.5597	11.7876
19	12.6157	12.6243
20	12.5704	12.579
21	12.5615	12.5701
22	12.5535	12.5621
23	12.3986	12.4531
24	12.3141	12.369
25	12.272	12.3271
26	11.9982	12.2355
27	11.9658	12.2286
28	11.821	12.2061
29	11.7169	12.1941
30	11.6719	12.5496
31	11.6192	12.5331
32	11.6076	12.5198
33	11.604	12.5038

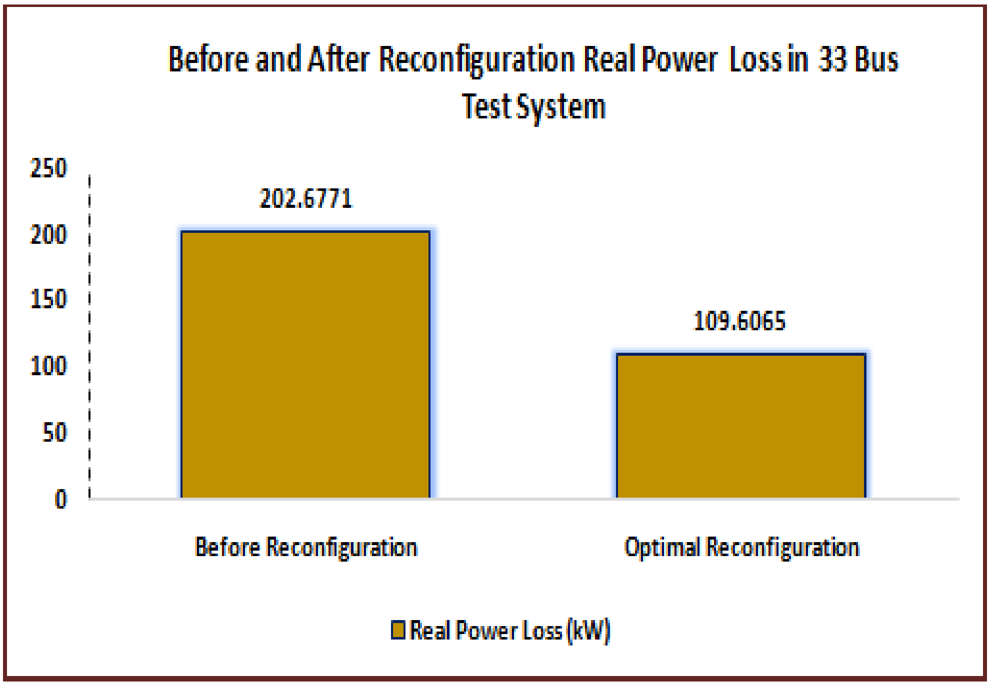
Graph 1 shows the results of using a computational model of a colony of artificial ants to determine the best possible values for the bus voltages in an IEEE 33 test system.



The bus voltage measurements recorded during the IEEE 33 Bus Test are shown in Graph 1.Before and after the configuration switch, the percentage of broken lines in the IEEE 33 Bus Test System are shown in Table 7.

	Before reconfiguration		After Reconfiguration	
Line No.	Loss kW)	Loss (kVAR)	Loss (kW)	Loss (kVAR)
1	12.2404	6.2397	7.2462	3.6938
2	51.7912	26.3789	28.3629	14.4461
3	19.9005	10.1351	8.0583	4.104
4	18.6989	9.5237	7.1419	3.6375
5	38.2486	33.018	14.1574	12.2213
6	1.9145	6.3285	1.8436	6.0943
7	4.838	1.5988	4.6575	1.5392
8	4.1805	3.0035	4.0231	2.8904
9	3.5609	2.524	3.4264	2.4287
10	0.5537	0.1831	0.5327	0.1761
11	0.8811	0.2914	0.8477	0.2803
12	2.6662	2.0978	2.5649	2.018
13	0.7292	0.9598	0.7014	0.9232
14	0.357	0.3177	0.3434	0.3056
15	0.2815	0.2055	0.2707	0.1977
16	0.2516	0.336	0.242	0.3231
17	0.0531	0.0417	0.0511	0.0401
18	0.161	0.1536	0.1607	0.1534
19	0.8322	0.7499	0.831	0.7488
20	0.1008	0.1177	0.1006	0.1175
21	0.0436	0.0577	0.0436	0.0576
22	3.1816	2.174	3.1534	2.1547
23	5.1437	4.0617	5.098	4.0256
24	1.2875	1.0074	1.276	0.9984
25	2.6009	1.3248	0.1492	0.076
26	3.329	1.695	0.1351	0.0688
27	11.3009	9.9637	0.2883	0.2541
28	7.8333	6.8242	0.1044	0.0909
29	3.8957	1.9843	0.166	0.1641
30	1.5936	1.575	0.3204	0.3735
31	0.2132	0.2485	0.2283	0.355
32	0.0132	0.0205	13.0803	13.0803

In Graph 2, we see the difference between the real power loss before and after the optimal reconfiguration was applied to the IEEE 33 bus test system.



the network parameters for the IEEE 33 bus test system are included in Table 10, including the base MVA and kV, real and reactive power loads, Ohmic losses with tie switches before and after reconfiguration, and more. Consult Table 8 for further details on the IEEE 33 Bus Test System.

Real power load	3715 kW
Reactive power load	2300 kVAR
Before reconfiguration I^2Rloss (ties-33,34,35,36,37)	202.6771 kW
After reconfiguration I^2R loss (ties-29,33,34,35,37)	109.6065 kW
Base MVA	100 MVA
Base kV	12.66 kV

After Reconfiguration Possible Combination Ties and Ohmic Loss in IEEE 33 Bus Test System is presented in the form of table shown in table 11.

IEEE 69 Bus Test System

In order to implement the strategy, the IEEE 69 bus testing system was used. The total active and reactive load of the test system is 3802.19 kW, with a reactive power factor of 2694.6 car. In case of a tie, you may use one of the other five switches in the system to choose the winner. The initial step was to divide the network into subnets using switches 1-68, and then to connect the subnets using switches 70-74. In all, the system consumes a lot of energy, measuring in at 225.0028 kW, 102.1659 car, and 247.1116 kVA. To disable the reconfiguration-switches and so isolate the gating switches, we may follow the instructions in Figure 7's footer (49, 64, 70, 71, and 72). A total of 71.1381 kW, 78.7572 car, and 106.1288 kVA is anticipated to be required to satisfy all electrical needs. We saw a loss reduction of 68.3834% after switching to the (Optimal) configuration.

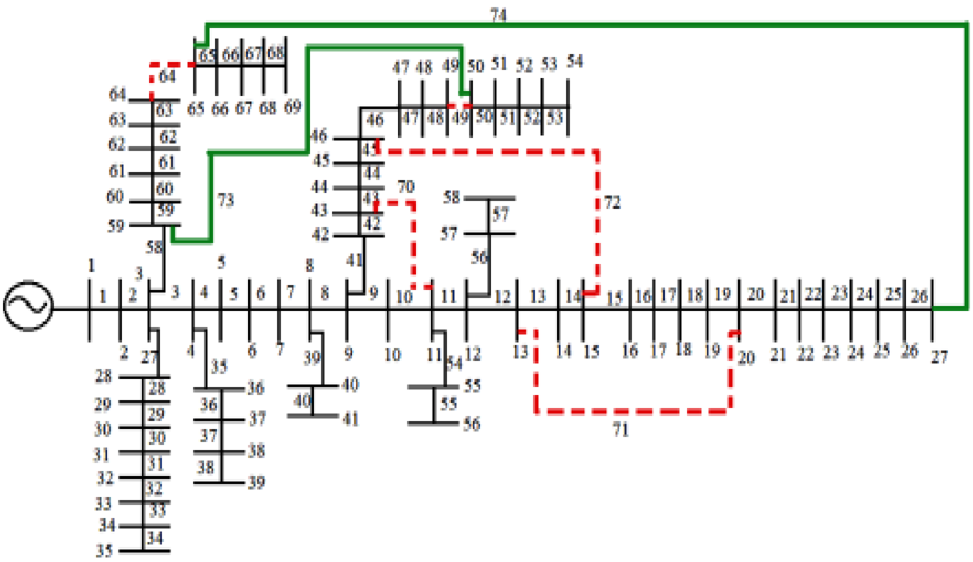


Figure 8 .33 Bus test system after reconfiguration

Table 9: IEEE 69 Bus Test System Line Data

From bus	To bus	R (ohm)	X (ohm)
1	2	0.0005	0.0012
2	3	0.0005	0.0012
3	4	0.0015	0.0036
4	5	0.0251	0.0294
5	6	0.366	0.1864
6	7	0.3811	0.1941
7	8	0.0922	0.047
8	9	0.0493	0.0251
9	10	0.819	0.2707
10	11	0.1872	0.0619
11	12	0.7114	0.2351
12	13	1.03	0.34
13	14	1.044	0.345
14	15	1.058	0.3496
15	16	0.1966	0.065
16	17	0.3744	0.1238
17	18	0.0047	0.0016
18	19	0.3276	0.1083
19	20	0.2106	0.0696
20	21	0.3416	0.1129
21	22	0.014	0.0046
22	23	0.1591	0.0526
23	24	0.3463	0.1145
24	25	0.7488	0.2475
25	26	0.3089	0.1021
26	27	0.1732	0.0572
3	28	0.0044	0.0108
28	29	0.064	0.1565
29	30	0.3978	0.1315

30	31	0.0702	0.0232
31	32	0.351	0.116
32	33	0.839	0.2816
33	34	1.708	0.5646
34	35	1.474	0.4873
4	36	0.0034	0.0084
36	37	0.0851	0.2083
37	38	0.2898	0.7091
38	39	0.0822	0.2011
8	40	0.0928	0.0473
40	41	0.3319	0.1114
9	42	0.174	0.0886
42	43	0.203	0.1034
43	44	0.2842	0.1447
44	45	0.2813	0.1433
45	46	1.59	0.5337
46	47	0.7837	0.263
47	48	0.3042	0.1006
48	49	0.3861	0.1172
49	50	0.5075	0.2585
50	51	0.0974	0.0496
51	52	0.145	0.0738
52	53	0.7105	0.3619
53	54	1.041	0.5302
11	55	0.2012	0.0611
55	56	0.0047	0.0014
12	57	0.7394	0.2444
57	58	0.0047	0.0016
3	59	0.0044	0.0108
59	60	0.064	0.1565
60	61	0.1053	0.123
60	61	0.1053	0.123
61	62	0.0304	0.0355
62	63	0.0018	0.0021
63	64	0.7283	0.8509
64	65	0.31	0.3623
65	66	0.041	0.0478
66	67	0.0092	0.0116
67	68	0.1089	0.1373
68	69	0.0009	0.0012
11	43	0.5	0.5
13	21	0.5	0.5
46	15	1	1.5
50	59	2	1
27	65	1	1.5

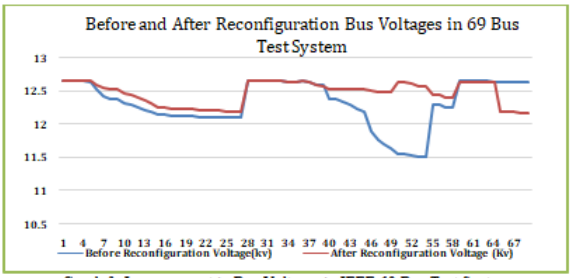
See Table 10 for IEEE 69 Bus Test System Bus Parameters.

Bus_I	Pd	Qd	Bs	Vm	Va	Base kV	Vmax	Vmin
1	0	0	0	1	0	12.66	1.1	0.9
2	0	0	0	1	0	12.66	1.1	0.9
3	0	0	0	1	0	12.66	1.1	0.9
4	0	0	0	1	0	12.66	1.1	0.9
5	0	0	0	1	0	12.66	1.1	0.9
6	2.6	2.2	0	1	0	12.66	1.1	0.9
7	40.4	30	0	1	0	12.66	1.1	0.9
8	75	54	0	1	0	12.66	1.1	0.9
9	30	22	0	1	0	12.66	1.1	0.9
10	28	19	0	1	0	12.66	1.1	0.9
11	145	104	0	1	0	12.66	1.1	0.9
12	145	104	0	1	0	12.66	1.1	0.9
13	8	5.5	0	1	0	12.66	1.1	0.9
14	8	5.5	0	1	0	12.66	1.1	0.9
15	0	0	0	1	0	12.66	1.1	0.9
16	45.5	30	0	1	0	12.66	1.1	0.9
17	60	35	0	1	0	12.66	1.1	0.9
18	60	35	0	1	0	12.66	1.1	0.9
19	0	0	0	1	0	12.66	1.1	0.9
20	1	0.6	0	1	0	12.66	1.1	0.9
21	114	81	0	1	0	12.66	1.1	0.9
22	5.3	3.5	0	1	0	12.66	1.1	0.9
23	0	0	0	1	0	12.66	1.1	0.9
24	28	20	0	1	0	12.66	1.1	0.9
25	0	0	0	1	0	12.66	1.1	0.9
26	14	10	0	1	0	12.66	1.1	0.9
27	14	10	0	1	0	12.66	1.1	0.9
28	26	18.6	0	1	0	12.66	1.1	0.9
29	26	18.6	0	1	0	12.66	1.1	0.9
30	0	0	0	1	0	12.66	1.1	0.9
31	0	0	0	1	0	12.66	1.1	0.9
32	0	0	0	1	0	12.66	1.1	0.9
33	14	10	0	1	0	12.66	1.1	0.9
34	19.5	14	0	1	0	12.66	1.1	0.9
35	6	4	0	1	0	12.66	1.1	0.9
36	0	0	0	1	0	12.66	1.1	0.9
37	79	56.4	0	1	0	12.66	1.1	0.9
38	384.7	274.5	0	1	0	12.66	1.1	0.9
39	384.7	274.5	0	1	0	12.66	1.1	0.9
40	40.5	28.3	0	1	0	12.66	1.1	0.9
41	3.6	2.7	0	1	0	12.66	1.1	0.9
42	4.35	3.5	0	1	0	12.66	1.1	0.9
43	26.4	19	0	1	0	12.66	1.1	0.9
44	24	17.2	0	1	0	12.66	1.1	0.9
45	0	0	0	1	0	12.66	1.1	0.9
46	0	0	0	1	0	12.66	1.1	0.9
47	0	0	0	1	0	12.66	1.1	0.9
48	100	72	0	1	0	12.66	1.1	0.9
49	0	0	0	1	0	12.66	1.1	0.9
50	1244	888	0	1	0	12.66	1.1	0.9
51	32	23	0	1	0	12.66	1.1	0.9
52	0	0	0	1	0	12.66	1.1	0.9
53	227	162	0	1	0	12.66	1.1	0.9
54	59	42	0	1	0	12.66	1.1	0.9
55	18	13	0	1	0	12.66	1.1	0.9
56	18	13	0	1	0	12.66	1.1	0.9
57	28	20	0	1	0	12.66	1.1	0.9
58	28	20	0	1	0	12.66	1.1	0.9
59	26	18.55	0	1	0	12.66	1.1	0.9
60	26	18.55	0	1	0	12.66	1.1	0.9
61	0	0	0	1	0	12.66	1.1	0.9
62	24	17	0	1	0	12.66	1.1	0.9
63	24	17	0	1	0	12.66	1.1	0.9
64	1.2	1	0	1	0	12.66	1.1	0.9
65	0	0	0	1	0	12.66	1.1	0.9
66	6	4.3	0	1	0	12.66	1.1	0.9
67	0	0	0	1	0	12.66	1.1	0.9
68	39.22	26.3	0	1	0	12.66	1.1	0.9
69	39.22	26.3	0	1	0	12.66	1.1	0.9

We may calculate the active power as 3802.19 kW at a voltage of 12.66 kV and a current of 100 MVA, and the reactive power as 2694.6 overmeasurement System for IEEE 69 Bus Voltage Upgrade

Bus No.	Before Reconfiguration Voltage (kV)	After Reconfiguration Voltage (kV)
1	12.66	12.66
2	12.6596	12.6598
3	12.6592	12.6595
4	12.658	12.6589
5	12.6476	12.6544
6	12.5345	12.6064
7	12.4168	12.5565
8	12.3888	12.5448
9	12.3744	12.5392
10	12.3111	12.4696
11	12.2972	12.4543
12	12.2571	12.4086
13	12.2201	12.3632
14	12.1834	12.318
15	12.1471	12.273
16	12.1403	12.2647
17	12.1292	12.2505
18	12.129	12.2503
19	12.1232	12.2417
20	12.1194	12.2362
21	12.1133	12.2272
22	12.1132	12.227
23	12.1123	12.2248
24	12.1103	12.2199
25	12.1081	12.2114
26	12.1073	12.2079
27	12.107	12.2062
28	12.6591	12.6594
29	12.6582	12.6585
30	12.6566	12.657
31	12.6564	12.6567
32	12.655	12.6554
33	12.6518	12.6521
34	12.6475	12.6479
35	12.6467	12.647
36	12.6573	12.6582
37	12.6416	12.6424
38	12.5929	12.5938
39	12.586	12.5869
40	12.3883	12.5444
41	12.3882	12.5442
42	12.3391	12.5363
43	12.2981	12.5329
44	12.2414	12.5291
45	12.1861	12.526
46	11.9016	12.5102
47	11.7616	12.5024
48	11.7074	12.4994
49	11.6438	12.4994
50	11.5502	12.6425
51	11.5465	12.6375
52	11.5416	12.6155
53	11.5176	12.5832
54	11.5103	12.5821
55	12.2964	12.4543
56	12.2964	12.4529
57	12.253	12.4086
58	12.2529	12.4086
59	12.659	12.6406
60	12.6568	12.6395
61	12.6548	12.6393
62	12.6542	12.6392
63	12.6542	12.6366
64	12.6454	12.6366
65	12.6417	12.2061
66	12.6412	12.2047
67	12.6411	12.2047
68	12.6398	12.1875
69	12.6398	12.181

Graph 3 shows the elevated bus voltages that occurred as a consequence of using the artificial ant colony optimization strategy in the IEEE 69 bus test system.

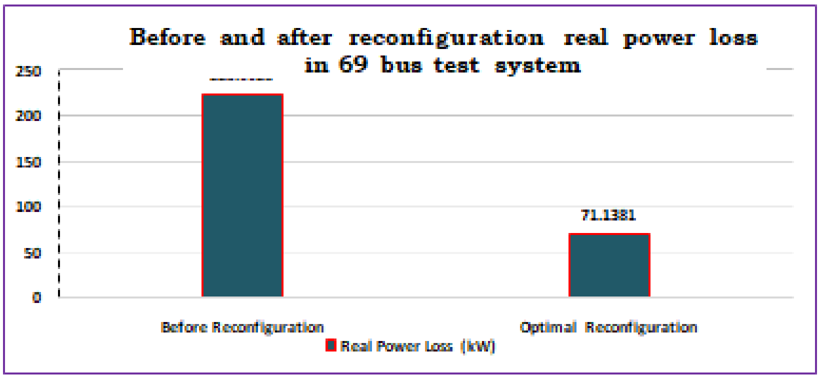


Graph 3: Improvement in Bus Voltages in IEEE 69 Bus Test System

Line segment losses before and after re-configuring the IEEE 69 Bus Test System Table 12.

	Before Reconfiguration		After Reconfiguration	
Line No.	Loss (kW)	Loss (kVAR)	Loss (kW)	Loss (kVAR)
1	0.075	0.18	0.0241	0.0578
2	0.075	0.18	0.0241	0.0578
3	0.195	0.468	0.0605	0.1451
4	1.937	2.2688	0.3497	0.4096
5	28.2447	14.3847	5.0997	2.5972
6	29.3528	14.9498	5.2859	2.6922
7	6.8956	3.5151	1.1933	0.6083
8	3.3756	1.7186	0.514	0.2617
9	4.7784	1.5794	5.7635	1.905
10	1.015	0.3356	1.2335	0.4079
11	2.1927	0.7246	2.8493	0.9416
12	1.2875	0.425	1.9375	0.6396
13	1.247	0.4121	1.8934	0.6257
14	1.2061	0.3985	1.8485	0.6108
15	0.2241	0.0741	0.3435	0.1136
16	0.3209	0.1061	0.5224	0.1728
17	0.0026	0.0009	0.0047	0.0016
18	0.1044	0.0345	0.2221	0.0734
19	0.0671	0.0222	0.1428	0.0472
20	0.1077	0.0356	0.2299	0.076
21	0.0005	0.0002	0.0029	0.001
22	0.0051	0.0017	0.0311	0.0103
23	0.0112	0.0037	0.0678	0.0224
24	0.006	0.002	0.0935	0.0309
25	0.0025	0.0008	0.0386	0.0127
26	0.0003	0.0001	0.0165	0.0055
27	0.0003	0.0009	0.0003	0.0009
28	0.0026	0.0063	0.0026	0.0063
29	0.0058	0.0019	0.0058	0.0019
30	0.001	0.0003	0.001	0.0003
31	0.0051	0.0017	0.0051	0.0017
32	0.0123	0.0041	0.0123	0.0041
33	0.0104	0.0034	0.0104	0.0034
34	0.0005	0.0002	0.0005	0.0002
35	0.0233	0.0575	0.0233	0.0575
36	0.5828	1.4266	0.5827	1.4264
37	1.6335	3.997	1.6333	3.9964
38	0.1159	0.2835	0.1159	0.2835
39	0.0018	0.0009	0.0017	0.0009
40	0	0	0	0
41	5.7813	2.9438	0.0405	0.0206
42	6.7115	3.4186	0.0445	0.0227
43	9.1248	4.6459	0.0424	0.0216
44	8.7902	4.4779	0.0273	0.0139
45	49.6849	16.6773	0.1545	0.0519
46	24.4894	8.2183	0.0762	0.0256
47	9.5058	3.1436	0.0296	0.0098
48	10.6711	3.2392	0	0
49	14.0263	7.1445	0.2079	0.1059
50	0.1121	0.0571	2.7145	1.3816
51	0.1349	0.0687	1.1888	0.6055
52	0.6612	0.3368	0.0011	0.0006
53	0.0412	0.021	0	0
54	0.0026	0.0008	0.3768	0.1122
55	0	0	0	0
56	0.0233	0.0077	0.0002	0.0001
57	0	0	11.6431	28.5785
58	0.0014	0.0034	0.0031	0.0077
59	0.0151	0.0369	0.0002	0.0002
60	0.0173	0.0202	0	0
61	0.005	0.0058	1.7727	2.0682
62	0.0002	0.0002	0	0
63	0.0487	0.0569	0.0222	0.0258
64	0.0201	0.0235	0	0
65	0.0027	0.0031	1.0653	1.3431
66	0.0005	0.0006	19.5372	26.0496
67	0.0061	0.0077	0.002	0.001
68	0	0	0	0

Graph 4 below compares the actual power loss in the IEEE 69 bus test system before and after a (better) reconfiguration.



In Graph 4, we see the 69-bus test system's real power loss before and after the system reconfiguration.
In Table 17, we can see the actual power used, the reactive power used, the Ohmic losses with tie switches, the base MVA, and the base kV for the IEEE 69 bus test system.

13. CONCLUSION

The major aims of this work are to balance loads, restore services, and decrease Holmic losses in the distribution system. An IEEE 4-feeder test system with varying degrees of failure at numerous sites was brought back online, and the IEEE 3-feeder system is stable. The minimum voltage at node18 is 11.5597kV before reconfiguration and is increased to 11.7876kV after reconfiguration, resulting in an ideal reduction of Holmic power loss of 45.9206%, apparent power loss of 44.7664%, and reactive power loss of 42.2543%. IEEE 69 bus system Holmic power loss is best reduced by lowering Holmic power loss by 68.3834%, apparent power loss by 57.0522%, and These goals were realized by a reorganization based on the optimization principles of artificial ant colonies.

14. RESULTS

IEEE Four Feeder Service Restoration

Thesimulation results for re-establishing IEEE 4 feeder service after a distribution system reconfiguration using AACO are shown in Table 13.

Table 13. Effects of a Defective Four-Feeder System on Several Locations

Feeder	Fault at	Optimal switching operation	LBI
A	Switch-1	Closed Switches - 6&20 Open Switch - 15	0.200853
B	Z8	Closed Switch - 9	0.131974
C	Z13	Closed Switches - 19&30 Open Switch - 35	0.0075
C	Z14	Closed Switch - 20	0.048007
D	Z17	Closed Switches - 10,19&29 Open Switches - 15&24	0.140506

A problem with feeder-C at Z13 was detected by the IEEE four-feeder test system. Compared to the methods used in the mentioned studies, our method results in the lowest LBI value (Table 3). Table14. Service has been fully restored, according to tests conducted after the four-feeder system was put into place.

Method	LBI value for the same fault on feeder-C at position Z13
Dr.P.Ravi Babu[22]	0.0100
Dr.P.Ravi Babu[23]	0.0124
Proposed method	0.0075

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